

ATARI® 400/800™

ATARI® HOME COMPUTER SYSTEM

**OPERATING SYSTEM
USER'S MANUAL**



A Warner Communications Company



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PREFACE	17
1 INTRODUCTION	18
GENERAL DESCRIPTION OF THE ATARI COMPUTER SYSTEM	18
Conventions Used in This Manual	20
HEXADECIMAL NUMBERS	20
MEMORY ADDRESSES	20
KILOBYTES OF MEMORY	20
PASCAL AS AN ALGORITHM-SPECIFICATION LANGUAGE	20
MEMORY LAYOUTS	20
BACKUS-NAUR FORM (BNF)	21
OS-EQUATE FILENAMES	21

2	OPERATING SYSTEM FUNCTIONAL ORGANIZATION	22
	Input/Output Subsystem	22
	Interrupt Processing	22
	Initialization	22
	Power-Up	22
	System Reset	23
	Floating Point Arithmetic Package	24
3	CONFIGURATIONS	25
	Program Environments	25
	Blackboard Mode	25
	Cartridge	26
	Diskette-Boot	26
	Cassette-Boot	26
	RAM Expansion	27
	Peripheral Devices	27
	Game Controllers	27
	Program Recorder	27
	Serial Bus Devices	28
4	SYSTEM MEMORY UTILIZATION	29
	RAM Region	29
	Page 0	30
	Page 1	30
	OS Data Base	30
	User Workspace	31
	Boot Region	31
	Screen Display List and Data	31
	Free Memory Region	31

Cartridges A and B	31
Mapped I/O	32
Resident OS and Floating Point Package ROM	32
Central Data Base Description	32
Memory Dynamics	32
System Initialization Process	33
Changing Screen Modes	33
5 I/O SUBSYSTEM	34
Central I/O Utility	36
CIO Design Philosophy	37
DEVICE INDEPENDENCE	37
DATA ACCESS METHODS	37
MULTIPLE DEVICE/FILE CONCURRENCY	38
UNIFIED ERROR HANDLING	38
DEVICE EXPANSION	38
CIO CALLING MECHANISM	38
HANDLER ID -- ICHID [0340]	39
DEVICE NUMBER -- ICDNO [0341]	39
COMMAND BYTE -- ICCMD [0342]	40
STATUS -- ICSTA [0343]	40
BUFFER ADDRESS	
ICBAL[0344] AND ICBAH [0345]	40
PUT ADDRESS --	
ICPTL [0346] AND ICPTH [0347]	40
BUFFER LENGTH/BYTE COUNT --	
ICBLL [0348] and ICBLH [0349]	40
AUXILIARY INFORMATION --	
ICAX1 [034A] and ICAX2 [034B]	40
REMAINING BYTES (ICAX3-ICAX6)	41

CIO Functions	41
OPEN -- Assign Device/Filename to IOCB and Ready for Access	41
CLOSE -- Terminate Access to Device/File and Release IOCB	42
GET CHARACTERS -- Read n Characters (Byte-Aligned Access)	43
PUT CHARACTERS -- Write n Characters (Byte-Aligned Access)	43
GET RECORD -- Read Up To n Characters (Record-Aligned Access)	44
PUT RECORD -- Write Up To n Characters (Record-Aligned Access)	44
GET STATUS -- Return Device-Dependent Status Bytes	45
SPECIAL -- Special Function	45
Device/Filename Specification	46
I/O Example	47
Device Specific Information	50
Keyboard Handler	50
CIO Function Descriptions	51
Theory of Operation	51
Display Handler (S:)	54
Screen Modes	54
TEXT MODE 0	54
TEXT MODES 1 AND 2	55
GRAPHICS MODES (Modes 3 Through 11)	56
SPLIT-SCREEN CONFIGURATIONS	56
CIO Function Descriptions	57
User-Alterable Data Base Variables	61
Theory of Operation	62
Screen Editor (E:)	66
CIO Function Descriptions	67
User-Alterable Data Base Variables	70
Cassette Handler (C:)	72
CIO Function Descriptions	72
Theory of Operation	74
File Structure	75

Printer Handler (P:)	76
CIO Function Descriptions	76
Theory of Operation	78
Disk File Manager (D:)	78
CIO Function Descriptions	79
Device/Filename Specification	81
Filename Wildcarding	82
Special CIO functions	84
Theory of Operation	87
FMS Diskette Utilization	89
FMS BOOT RECORD FORMAT	90
BOOT PROCESS MEMORY MAP	92
VOLUME TABLE OF CONTENTS	93
FILE DIRECTORY FORMAT	94
FMS FILE SECTOR FORMAT	95
Non-CIO I/O	96
Resident Device Handler Vectors	96
Resident Diskette Handler	97
Diskette Handler Commands	99
Serial Bus I/O	101
 6 INTERRUPT PROCESSING	 102
Chip-Reset	103
Nonmaskable Interrupts	103
Stage 1 VBLANK Process	104
Stage 2 VBLANK Process	105
Maskable Interrupts	107
Interrupt Initialization	108
System Timers	109
Usage Notes	109
POKEY Interrupt Mask	110
Setting Interrupt and Timer Vectors	110
Stack Content at Interrupt Vector Points	111
Miscellaneous Considerations	112
Flowcharts	113

7	SYSTEM INITIALIZATION	116
	Power-Up Initialization (Coldstart) Procedure	116
	System Reset Initialization (Warmstart) Procedure	119
8	FLOATING POINT ARITHMETIC PACKAGE	121
	Functions/Calling Sequences	122
	ASCII to Floating Point Conversion (AFP)	122
	Floating Point to ASCII Conversion (FASC)	122
	Integer to Floating Point Conversion (IFP)	123
	Floating Point to Integer Conversion (FPI)	123
	Floating Point Addition (FADD)	124
	Floating Point Subtraction (FSUB)	124
	Floating Point Multiplication (FMUL)	124
	Floating Point Division (FDIV)	125
	Floating Point Logarithms (LOG and LOG10)	125
	Floating Point Exponentiation (EXP and EXP10)	126
	Floating Point Polynomial Evaluation (PLYEVL)	126
	Clear FRO (ZFRO)	127
	Clear Page-Zero Floating Point Number (ZF1)	127
	Load Floating Point Number to FRO (FLDOR and FLDOP)	127
	Load Floating Point Number to FR1 (FLD1R and FLD1P)	128
	Store Floating Point Number From FRO (FSTOR and FSTOP)	128
	Move Floating Point Number From FRO to FR1 (FMOVE)	128
	Resource Utilization	128
	Implementation Details	129
9	ADDING NEW DEVICE HANDLERS/PERIPHERALS	131
	Device Table	134
	CIO/Handler Interface	134
	Calling Mechanism	135
	Handler Initialization	136
	Functions Supported	136
	Error Handling	140
	Resource Allocation	140
	ZERO-PAGE RAM	141
	NONZERO-PAGE RAM	141
	STACK SPACE	142
	Handler/SIO Interface	142

Calling Mechanism	142
Functions Supported	144
Error Handling	144
Serial I/O Bus Characteristics and Protocol	145
Hardware/Electrical Characteristics	145
Serial Port Electrical Specifications	147
Bus Commands	147
COMMAND FRAME	148
COMMAND FRAME ACKNOWLEDGE	148
DATA FRAME	149
OPERATION COMPLETE	149
Bus Timing	150
Handler Environment	152
Bootable Handler	153
Cartridge Resident Handler	153
Flowcharts	153
10 PROGRAM ENVIRONMENT AND INITIALIZATION	157
Cartridge	157
Cartridge Without Booted Support Package	158
Cartridge With Booted Support Package	158
Diskette-Booted Software	159
Diskette-Boot File Format	159
Diskette-Boot Process	160
Sample Diskette-Bootable Program Listing	161
Program to Create Diskette-Boot Files	162
Cassette-Booted Software	164
Cassette-Boot File Format	165
Cassette-Boot Process	165
Sample Cassette-Bootable Program Listing	167
Program to Create Cassette-Boot Files	168

11	ADVANCED TECHNIQUES AND APPLICATION NOTES	170
	Sound Generation	170
	Capabilities	170
	Conflicts With OS	170
	Screen Graphics	171
	Hardware Capabilities	171
	OS Capabilities	171
	Cursor Control	171
	Color Control	171
	Alternate Character Sets	172
	Player/Missile Graphics	174
	Hardware Capabilities	174
	Conflicts With OS	174
	Reading Game Controllers	174
	Keyboard Controller Sensing	174
	Front Panel Connectors as I/O Ports	176
	Hardware Information:	176
	Software Information:	177
	Other Miscellaneous Software Information:	179

APPENDICES

Appendix A -- CIO COMMAND BYTE VALUES	180
Appendix B -- CIO STATUS BYTE VALUES.	181
Appendix C -- SIO STATUS BYTE VALUES	182
Appendix D -- ATASCII CODES	183
Appendix E -- DISPLAY CODES (ATASCII)	184
Appendix F -- KEYBOARD CODES (ATASCII)	185
Appendix G -- PRINTER CODES (ATASCII)	186
Appendix H -- SCREEN MODE CHARACTERISTICS	188
Appendix I -- SERIAL BUS ID AND COMMAND SUMMARY	191
Appendix J -- ROM VECTORS	192
Appendix K -- DEVICE CHARACTERISTICS	194
Keyboard	194
Display	194
ATARI 410[TM] Program Recorder	194
ATARI 820[TM] 40-Column Impact Printer	195
ATARI 810[TM] Disk Drive	197
Appendix L -- OS DATA BASE VARIABLE FUNCTIONAL DESCRIPTIONS	200
Central Data Base Description	200
FUNCTIONAL INDEX TO DATA BASE VARIABLE DESCRIPTIONS	201
A. MEMORY CONFIGURATION	211

B. TEXT/GRAPHICS SCREEN	212
Cursor Control	212
Screen Margins	213
Text Scrolling	215
Attract Mode	215
Tabbing	216
Logical Text Lines	217
Split Screen	218
Displaying Control Characters	220
Escape (Display Following Control Character)	221
Display Control Characters Mode	221
Bit-Mapped Graphics	221
Internal Working Variables	222
Internal Character Code Conversion	224
C. DISKETTE HANDLER	225
D. CASSETTE	225
Baud Rate Determination	226
Cassette Mode	227
Cassette Buffer	227
Internal Working Variables	228
E. KEYBOARD	229
Key Reading and Debouncing	229
Special Functions	230
Start/Stop	230
Autorepeat	231
Inverse Video Control	232
Console Keys: [SELECT], [START], and [OPTION]	232
F. PRINTER	232
Printer-Buffer	233
Internal Working Variables	233

G. CENTRAL I/O ROUTINE (CIO)	233
User Call Parameters	233
I/O Control Block	233
Device Status	234
Device Table	235
CIO/Handler Interface Parameters	235
Zero-Page IOCB	235
Internal Working Variables	236
H. SERIAL I/O ROUTINE (SIO)	237
User Call Parameters	237
Device Control Block	237
Bus Sound Control	238
Serial Bus Control	238
Retry Logic	238
Checksum	239
Data Buffering	240
General Buffer Control	240
Command Frame Output Buffer	240
Receive/Transmit Data Buffering	241
SIO Timeout	241
Internal Working Variables	242
J. ATARI CONTROLLERS	243
Joysticks	243
Paddles	244
Light Pen	245
Driving Controllers	246
K. DISK FILE MANAGER	247
L. DISK UTILITY POINTER	248
M. FLOATING POINT PACKAGE	248
N. Power-Up and System Reset	249
RAM Sizing	249
Diskette/Cassette-Boot	250
Environment Control	251

P. INTERRUPTS	252
System Timers	253
Real Time Clock	253
System Timer 1	253
System Timer 2	254
System Timers 3, 4 and 5	254
RAM Interrupt Vectors	255
NMI Interrupt Vectors	255
IRQ Interrupt Vectors	255
Hardware Register Updates	256
Internal Working Variables	258
R. USER AREAS	258
Alphabetical List of Data Base Variables	259
Memory Address Ordered List of Data Base Variables	266
Floating Point Package Variables	270
INDEX	271

TABLE OF ILLUSTRATIONS

Figure 1-1.	ATARI Home Computer Block Diagram	19
Figure 1-2.	Memory Layout Chart	20
Figure 4-1.	6502 System Memory Map	29
Figure 4-2.	Mapped I/O	32
Figure 5-1.	I/O Subsystem Structure Flow Diagram	35
Figure 5-2.	CID Calling Mechanism	38
Figure 5-3.	An I/O Example	49
Figure 5-4.	Keycode to ATASCII Conversion Table	53
Figure 5-5.	Text Modes 1 and 2 Data Form	56
Figure 5-6.	Graphics Modes 3-11 GET Data Form	58
Figure 5-7.	Graphics Modes 3-11 PUT Data Form	59
Figure 5-8.	Screen Display Block Diagram	64
Figure 5-9.	Cassette Handler Record Format	74
Figure 5-10.	Device/Filename Syntax	81
Figure 5-11.	File Management Subsystem Diskette Sector Utilization Map	89
Figure 5-12.	File Management Subsystem Boot Record Format	90
Figure 5-13.	File Management Subsystem Boot Process Memory Map	92
Figure 5-14.	File Management Subsystem Volume Table of Contents	93
Figure 5-15.	File Management Subsystem Volume Bit Map	93
Figure 5-16.	File Directory Format	94
Figure 5-17.	File Management Subsystem File Sector Format	95
Figure 5-18.	Resident Device Handler Vectors	96
Figure 5-19.	DVSTAT 4-Byte Operation Status Format	100

Figure 6-1.	List of System Interrupt Events	102
Figure 6-2.	Interrupt RAM Vector Initialization	108
Figure 6-3.	POKEY Interrupt Mask Example	110
Figure 6-4.	Interrupt and Timer Vector RAM Stack	
	Content Table	112
Figure 9-1.	I/O Subsystem Flow Diagram	133
Figure 9-2.	Device Table Format	134
Figure 9-3.	Handler Vector Table	135
Figure 9-4.	Serial Bus Connector Pin Descriptions	146
Figure 9-5.	Serial Bus Command Frame Format	148
Figure 9-6.	Serial Bus Timing Diagram	151
Figure 10-1.	Cartridge Header Format	157
Figure 10-2.	Diskette Boot File Format	159
Figure 10-3.	Diskette-Bootable Program Listing Example	162
Figure 10-4.	Sample Cassette-Bootable Program	168
Figure 11-1.	User-Defined Character Set Bit Memory Address	172
Figure 11-2.	User-Defined 8 x 8 Character Matrix Bit Table	173
Figure 11-3.	Character Base Diagram	173
Figure 11-4.	Reading Data From an ATARI Keyboard Controller	176
Figure 11-5.	ATARI Keyboard Controller Variable/Register Value Table	176
Figure 11-6.	Using Front Panel Connectors As I/O Ports: Pin Function Tables	179

PREFACE

This manual describes the resident Operating System (OS) for the ATARI® Home Computer, for readers who are familiar with the internal behavior of the system. It discusses:

- o System functions and utilization techniques
- o Subsystem relationships and organization
- o Characteristics of the ATARI peripheral devices that can be attached to the ATARI400[TM] and ATARI 800[TM] Home Computer
- o Advanced techniques for going beyond the basic OS capabilities
- o The general features of the computer system hardware used by the OS.

It would be helpful to have a familiarity with programming concepts and terminology, assembly language programming in general, the Synertek 6502 in particular, and digital hardware concepts and terminology. you will be provided with the information you need to use the OS resources, without resorting to trial-and-error techniques or the OS listing. Supporting information for tasks that involve OS listing references is also provided.

This manual does not present a comprehensive description of the hardware used to provide OS capabilities. The programmer who needs to go beyond the capabilities described should consult the ATARI Home Computer Hardware Manual.

1 INTRODUCTION

GENERAL DESCRIPTION OF THE ATARI HOME COMPUTER SYSTEM

Operating systems in the ATARI® 400[™] and ATARI 800[™] Home Computer are identical. The primary differences between the two are:

- o Physical packaging
- o The ATARI 400 Computer console has one cartridge slot, the ATARI 800 Computer console has two cartridge slots
- o The ATARI 400 Home Computer contains 16K RAM and cannot be expanded. The ATARI 800 Home Computer can be expanded to a maximum of 48K RAM.
- o The ATARI 800 Computer has a monitor jack; the ATARI 400 Computer does not.

The Hardware Circuitry

- o Produces both character and point graphics for black and white (B/W) or color television.
- o Produces four independent audio channels (frequency controlled) which use the television sound system.
- o Provides one bi-level audio output in the base unit.
- o Interfaces with up to four Joysticks and eight Paddle Controllers.
- o Interfaces with a serial I/O bus for expansion.
- o Contains a built-in keyboard

Figure 1-1 presents a simplified block diagram of the hardware. See the hardware manual for supporting documentation.

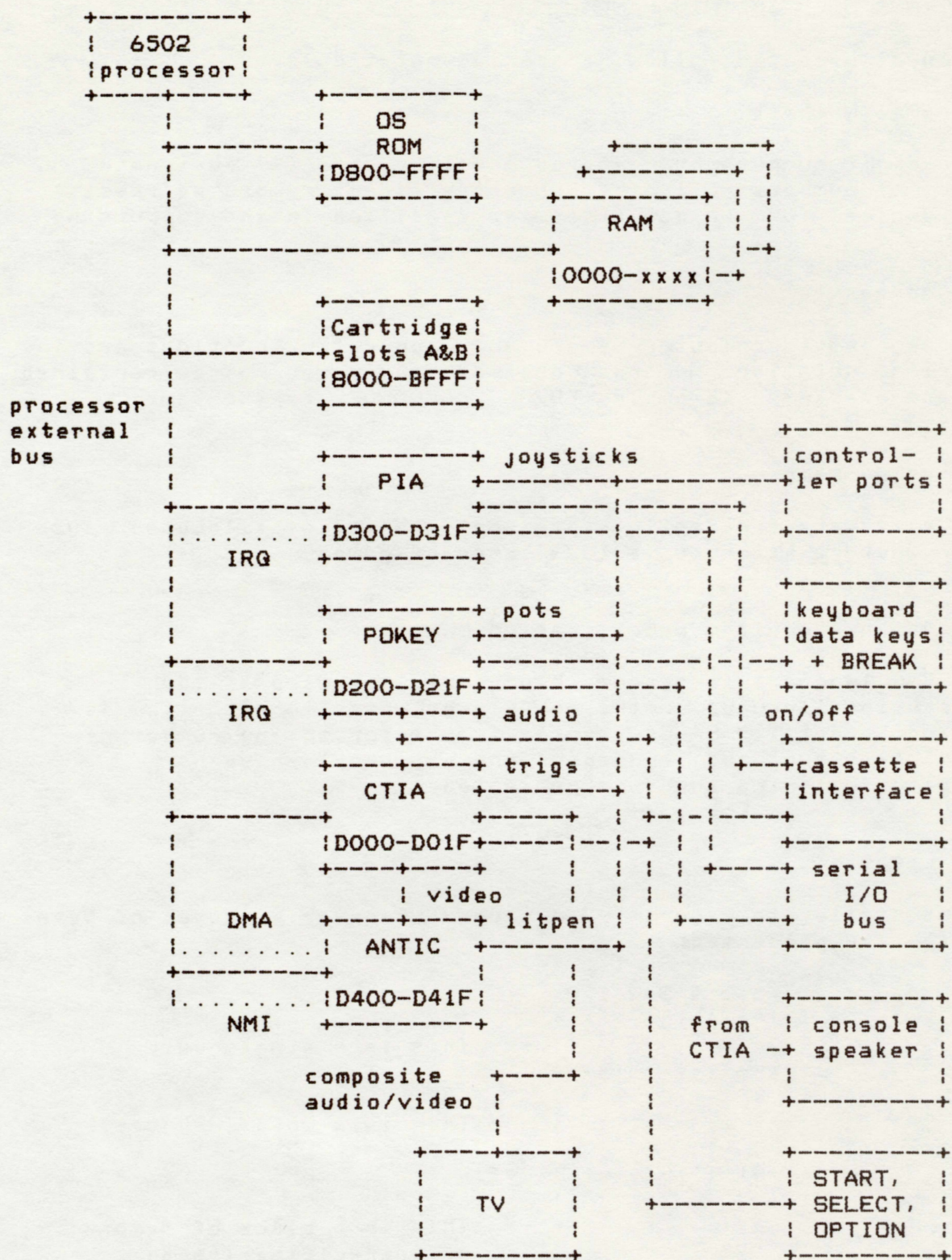


Figure 1-1. ATARI Home Computer Block Diagram

CONVENTIONS USED IN THIS MANUAL

This manual uses the following special notations:

Hexadecimal Numbers

All two-digit numbers preceded by a dollar sign (\$) designate hexadecimal numbers. All other numbers (except memory addresses) are in decimal form unless otherwise specified in the supporting text.

Memory Addresses

All references to computer memory and mapped I/O locations are in hexadecimal notation. Memory addresses may or may not be contained in square brackets. (Example: [D20F] and D20F are the same address.)

Kilobytes of Memory

Memory sizes are frequently expressed in units of kilobytes, such as 32K, where a kilobyte is 1024 bytes of memory.

PASCAL As an Algorithm-Specification Language

The PASCAL language (procedure block only) is used as the specification language in the few places where an algorithm is specified in detail. PASCAL syntax is similar to any number of other block-structured languages, and you should have no difficulty following the code presented.

Memory Layouts

Diagrams similar to Figure 1-2 are used whenever pictures of bytes or tables are presented:

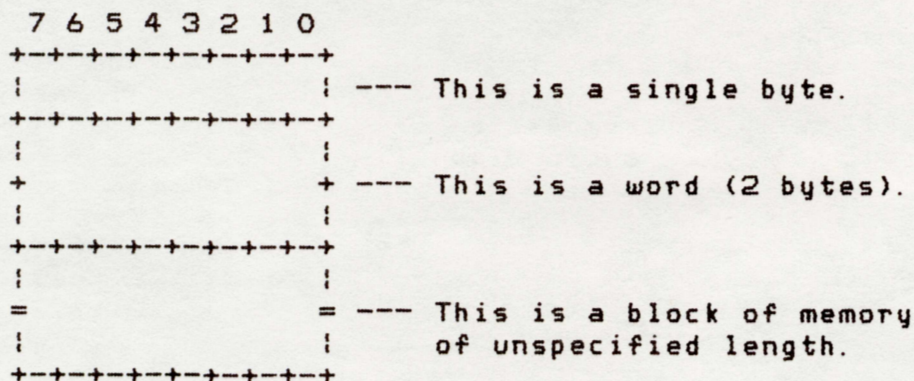


Figure 1-2. Memory Layout Chart

Bit 7 is the most significant bit (MSB) of the byte, and Bit 0 is the least significant bit (LSB).

In tables and figures, memory addresses always increase toward the bottom of the figure.

Backus-Naur Form

A modified version of Backus-Naur Form (BNF) is used to express some syntactic forms, where the following metalinguistic symbols are used:

`::=` is the substitution (assignment) operator.

`< >` a metasyntactic variable.

`|` separates alternative substitutions.

`[]` an optional construct.

Anything else is a syntactic literal constant, which stands for itself.

For Example:

`<device specification> ::= <device name>[<device number>]:`

`<device name> ::= C|D|E|K|I|R|S`

`<device number> ::= 1|2|3|4|5|6|7|8`

A "device specification" consists of a mandatory "device name," followed by an optional "device number," followed by the mandatory colon character. The device name in turn must be one of the characters shown as alternatives. The device number (if it is present) must be a digit 1 through 8.

OS Equate Filenames

Operating System ROM (Read Only Memory) and RAM (Random Access Memory) vector names, RAM database variable names and hardware register names are all referred to by the names assigned in the OS program equate list. When one of these names is used, the memory address is usually provided, such as `BOOTAD [0242]`.

2 OPERATING SYSTEM FUNCTIONAL ORGANIZATION

This section describes the various subsystems of the resident OS in general terms.

Input/Output Subsystem

The Input/Output (I/O) subsystem provides a high-level interface between the programs and the hardware. Most functions are device-independent, such as the reading and writing of character data; yet provisions have been made for device-dependent functions as well. All peripheral devices capable of dealing with character data have individual symbolic names (such as K,D,P, etc). and can be accessed using a Central I/O (CIO) routine.

A RAM data base provides access to controllers (joysticks and paddle controllers), which do not deal with character data. This RAM data base is periodically updated to show the states of these devices.

INTERRUPT PROCESSING

The interrupt system handles all hardware interrupts in a common and consistent manner. By default, all interrupts are fielded by the OS. At your discretion, individual interrupts (or groups of interrupts) can be fielded by the application program.

INITIALIZATION

The system provides two levels of initialization: power up and system reset. The OS performs power-up initialization each time the system power is switched to ON, and system reset initialization is performed each time the [SYSTEM.RESET] key is pressed.

Power-Up

The OS examines and notes the configuration of the unit whenever the system power is switched to ON. The system performs the following tasks at power up:

- o Determines the highest RAM address.
- o Clears all of RAM to zeros.
- o Establishes all RAM interrupt vectors.
- o Formats the device table.
- o Initializes the cartridge(s).

- o Sets up the screen for 24 x 40 text mode.
- o Boots the cassette if directed.
- o Checks cartridge slot(s) for diskette-boot instructions.
- o Boots the diskette if directed to do so and a disk drive unit is attached.
- o Transfers control to the cartridge, diskette-booted program, cassette-booted program, or blackboard program.

[SYSTEM. RESET]

Pressing the [SYSTEM. RESET] key causes the OS to perform these following tasks:

- o Clears the OS portion of RAM.
- o Rechecks top of RAM.
- o Reestablishes all RAM interrupt vectors.
- o Formats the device table.
- o Initializes the cartridge(s).
- o Sets up the screen for 24 x 40 text mode.
- o Transfers control to the cartridge, a diskette-booted program, a cassette-booted program, or the blackboard program.

Note that [SYSTEM. RESET] does not perform all the power-up tasks listed in the power-up section.

FLOATING POINT ARITHMETIC PACKAGE

The OS ROM contains a Floating Point (FP) package that is available to nonresident programs such as ATARI BASIC.

The package is not used by the other parts of the OS itself. The floating point numbers are stored as 10 BCD digits of mantissa, plus a 1-byte exponent. The package contains these routines:

- o ASCII-to-FP and FP-to-ASCII conversion.
- o Integer-to-FP and FP-to-integer conversion.
- o FP add, subtract, multiply and divide.
- o FP log, exp, and polynomial evaluation.
- o FP number clear, load, store, and move.

3 CONFIGURATIONS

The ATARI 400 and ATARI 800 Home Computers support a wide variety of configurations, each with a unique operating environment:

- o Cartridge(s) may or may not be inserted
- o Memory can be optionally added to the ATARI 800 Computer console in 16K increments
- o Many different peripheral devices can be attached to the serial I/O bus.

The OS accounts for all of these variables without requiring a change in the resident OS itself (see Section 2). The machine configuration is checked when power is first turned on and then is not checked again, unless system reset is used. A general discussion of some of the valid configurations follows.

PROGRAM ENVIRONMENTS

The OS allows one of four program types to be in control at any point in time:

- o The OS blackboard (ATARI Memo Pad) program
- o A cartridge-resident program
- o A diskette-booted program
- o A cassette-booted program

Control choice is based upon information in the cartridge(s), upon whether or not a disk drive is attached, and upon operator keyboard inputs. The exact algorithms are discussed in detail in Section 7.

Blackboard Mode

In blackboard mode, the screen is established as a 24 x 40 text screen. Anything entered from the keyboard goes to the screen without being examined, although all of the screen editing functions are supported. Blackboard mode is the lowest priority environment. You go there only by command from a higher

priority environment, or by default, if there is no other reasonable environment for the OS to enter. For example, typing BYE in BASIC causes the OS to enter the blackboard mode. The blackboard mode can be exited by pressing the [SYSTEM.RESET] key if it was entered from a higher environment.

Cartridge

An inserted cartridge normally provides the main control after initialization is complete (for example: ATARI BASIC, SUPER BREAKOUT[TM], BASKETBALL, COMPUTER CHESS, and others. All these cartridge programs interface directly with you in some way). Although a cartridge can provide a supporting function for some other program environment, this has not yet been done. Some cartridges (particularly keyboard-oriented ones) can change environments by entering special commands (such as "BYE") to go to blackboard mode or "DOS" to enter the disk utility. Other cartridges cannot change environments. Note that a hardware interlock prevents the removal or insertion of a cartridge with the power on; this feature causes the entire system to reinitialize with every cartridge change.

Diskette Boot

The diskette may or may not be booted when the system powers up with diskette-bootable software. This paragraph assumes that a diskette boot did occur. See Section 7 for boot condition explanations.

The diskette-booted software can take control as the Disk Utility Program (DUP) does under certain conditions, or can provide a supporting function as the File Management System (FMS) does. This environment is so flexible that it is difficult to generalize on its capabilities and restrictions. The only machine requirement (other than the disk drive) is that sufficient RAM be installed to support the program being booted.

Cassette-Boot

The cassette-boot environment is similar to the diskette-boot environment, although the cassette is limited as an I/O device. It is slow and can access only one file at a time in sequence. Note that the cassette-boot facility has no relation to the use of cassettes to store high-level language programs (e.g., programs written in ATARI BASIC), nor to the use of cassettes to store data.

RAM EXPANSION

Although you can expand RAM noncontiguously in the ATARI 800 Home Computer, the OS will only recognize RAM that is contiguous starting from location 0. Installation directions are provided with the purchased RAM modules. RAM can be added until it totals 48K. After 32K, additional RAM overlays first the right-cartridge addresses (32K to 40K) and then the left-cartridge addresses (40K to 48K). Note that in cases of conflict, the inserted cartridge has higher priority and disables the conflicting RAM in 8K increments. See Section 4 for a detailed discussion of system memory.

As a result of power-up, the OS will generate two pointers that define the lowest available RAM location and the highest available RAM location. The OS and diskette or cassette-booted software will determine the location of the lowest available RAM, while the number of RAM modules and the current screen mode will determine the highest available RAM.

PERIPHERAL DEVICES

Peripheral devices of several types can be added to the system using standard cables to either the serial bus or the connectors at the front of the computer console. The most common types deal with either transmission of bytes of data (usually serial bus) or transmission of sense information (usually game controllers).

Game Controllers

The OS periodically senses (50 or 60 times per second) the standard game controllers (Paddles and Joysticks) and the values read are stored in RAM. You can plug in, remove, and rearrange these controllers at will without affecting system operation, because the system will always try to read all of these controllers. The Driving Controllers are read, but not decoded, by the OS. Special instructions are required to read the keyboard controller (see Section 11).

Program Recorder

The ATARI 410[TM] Program Recorder is a special peripheral. It uses the serial bus to send and receive data, but does not conform to the protocol of the other peripherals that use the serial bus. The Program Recorder must also be the last device on the serial bus, because it does not have a serial bus extender connector as the other peripherals do. There can never be more than one Program Recorder connected to any system for the same reason. The system cannot sense the presence or absence of the Program Recorder, so it can be connected and disconnected at will.

Serial Bus Devices

A serial bus device conforms to the serial I/O bus protocol as defined in Section 9, but this does not include the Program Recorder. Each serial bus device has two identical connectors: a serial bus input, and a serial bus extender. Either connector can be used for either purpose. Peripherals can be "daisy chained" by cabling them together in a sequential fashion. There are usually no restrictions on the cabling order because each device has a unique identifier. Where restrictions exist, they will be mentioned in Section 5.

4 SYSTEM MEMORY UTILIZATION

Memory in the system is decoded in the full 64K range of the 6502 microcomputer and there are no provisions for additional mapping to extend memory. Memory is divided into four basic regions (with some overlap possible): RAM, cartridge area, I/O region and the resident OS ROM. The regions and their address boundaries are listed below (all addresses are in hexadecimal):

0000-1FFF = RAM (minimum required for operation)	8K	} 32K
2000-7FFF = RAM expansion area	24K	
8000-9FFF = Cartridge B, Cartridge A (half of 16K size) or RAM	8K	} 32K
A000-BFFF = Cartridge A or RAM	8K	
C000-CFFF = Unused	4K	
D000-D7FF = Hardware I/O decodes	2K	
D800-DFFF = Floating Point Package (OS)	2K	
E000-FFFF = Resident Operating System ROM	8K	

64K

Figure 4-1 6502 System Memory Map

This section will break these regions into even smaller functional divisions and provide detailed explanations of their usage.

RAM REGION

The OS and the control program share the RAM region. The RAM region can be further subdivided into the following sub regions for discussion purposes:

- Page 0 = 6502 page zero address mode region.
- Page 1 = 6502 stack region.
- Pages 2-4 = OS database and user workspace.
- Pages 5-6 = User program workspace.
- Pages 7-XX = Bootable software area/free RAM.*
- Pages XX-top of RAM = Screen display list and data.*

* Note that XX is a function of the screen graphics mode and the amount of RAM installed.

The paragraphs that follow describe how the OS uses RAM subregions, and presents user program recommendations.

Page 0

The architecture of the 6502 microcomputer instruction set and addressing modes gives page 0 special significance. References to addresses in that page (0000 to 00FF) are faster, require fewer instruction bytes, and provide the only mechanism for hardware indirect addressing. Page 0 should be used sparingly so that all possible users can have a portion of it. The OS permanently takes the lower half of page 0 (0000 to 007F). This portion can never be used by any outer environment unless the OS is completely disabled and all interrupts to the OS are eliminated.

The upper half of page 0 (0080 to 00FF) is available to outer environments with the following restriction: the floating point package, if used, requires 00D4 through 00FF.

Page 1

Page 1 is the 6502 hardware stack region; JSR instructions, PHA instructions, and interrupts all cause data bytes to be written to page 1. Conversely RTS, PLA, and RTI instructions all cause data bytes to be read from page 1. The 256 byte stack is adequate for normal subroutine calls plus interrupt process nesting, so no restrictions have been made on page 1 usage. It is obvious that a stack of this size is totally inadequate for deeply recursive processes or for nested processes with large local environments to be saved. So, for sophisticated applications, software maintained stacks must be implemented.

The 6502 stack pointer is initialized at power-up or system reset to point to location 01FF. The stack then pushes downward toward 0100. The stack will wrap around from 0100 to 01FF if a stack overflow condition occurs, because of the nature of the 6502's 8-bit stack pointer register.

OS Data Base

Locations 0200 through 047F are allocated by the OS for working variables, tables and data buffers. Portions of this region can be used only after you determine that nonconflict with the OS is guaranteed. For example, the printer and cassette buffers could be used if I/O operations to these devices are impossible within the controlling environment. The amount of work involved in determining nonconflict seems to be completely out of line with the benefits to be gained (except for a few trivial cases) and it is recommended that pages 2 through 4 not be used except by the OS.

User Workspace

Locations 0480 through 06FF are dedicated for outer environment use except when the floating point package is used. The floating point package uses locations 057E through 05FF.

Boot Region

Page 7 is the start of the "boot region." When software is booted from either the diskette or the cassette, it can start at the lowest free memory address (that is 0700) and proceed upward (although it can also start at any address above 0700 and below the screen display list). The top of this region defines the start of the "free memory" region. When the boot process is complete, a pointer in the data base contains the address of the next available location above the software just booted. When no software has been booted, this pointer contains the value 0700.

Screen Display List and Data

When the OS is handling the screen display, the display list that defines the screen characteristics and the current data that is contained on the screen are placed at the high address end of RAM. The bottom of this region defines the end of the free memory region and its location is a function of the screen mode currently in effect. A pointer in the data base contains the address of the last available location below the screen region.

Free Memory Region

The free memory region is all the RAM between the end of the boot region and the start of the screen region. The outer level application is responsible for managing the free memory region.

CARTRIDGES A AND B

There are two 8K regions reserved for plug-in cartridges. Cartridge B, that is the right-hand cartridge slot found only in the ATARI 800 Home Computer, has been allocated memory addresses 8000 through 9FFF. Cartridge A (the left-hand cartridge slot in the ATARI 800 Computer console, and the only slot in the ATARI 400 Computer console) has been allocated memory addresses A000 through BFFF and optionally 8000 through BFFF, for 16K cartridges. If a RAM module is plugged into the last slot such as to overlay any of these addresses, the RAM takes precedence as long as a cartridge is not inserted. However, if a cartridge is inserted, it will disable the entire conflicting RAM module in the last slot in 8K increments.

MAPPED I/O

The 6502 performs input/output operations by addressing the external support chips as memory; some chip registers are read/write while others are read-only or write-only (the ATARI Home Computer Hardware Manual gives descriptions of all of the external registers). While the entire address space from D000 to D7FF has been allocated for I/O decoding, only the following subregions are used:

D000-D01F = CTIA
D200-D21F = POKEY
D300-D31F = PIA
D400-D41F = ANTIC

Figure 4-2. Mapped I/O

RESIDENT OS AND FLOATING POINT PACKAGE ROM

The region from D800 through FFFF always contains the OS and the floating point package. Care should be taken to avoid using any entry points that are not guaranteed not to move, to allow for the possibility that another, but functionally compatible, OS can be generated in the future. The OS contains many vectored entry points at the end of the ROM and in RAM that will not move. The floating point package is not vectored, but all documented entry points will be fixed: Do not use undocumented routines found by scanning the listing. A list of the fixed ROM vectors can be found in Appendix J.

CENTRAL DATA BASE DESCRIPTION

See Appendix L.

MEMORY DYNAMICS

The free memory region is the area between the end of the boot region and the start of the screen region. As such, its limits are variable. MEMLO [02E7] defines the bottom of the free region, and MEMTOP [02E5] defines the top of the region. This section presents the conditions that cause the setup or alteration of these variables.

System Initialization Process

The OS determines the extent of the lowest block of contiguous RAM, and saves the limits. The Screen Editor is then opened, thus setting a new (and lower) value in MEMTOP. Diskette or cassette-booted software might be brought into memory, that would probably set a new (and higher) value in MEMLO (see Section 7). MEMLO and MEMTOP will define the maximum amount of free memory available when the application program finally gets control. That amount of free memory can later decrease, as described in the next paragraph.

Changing Screen Modes

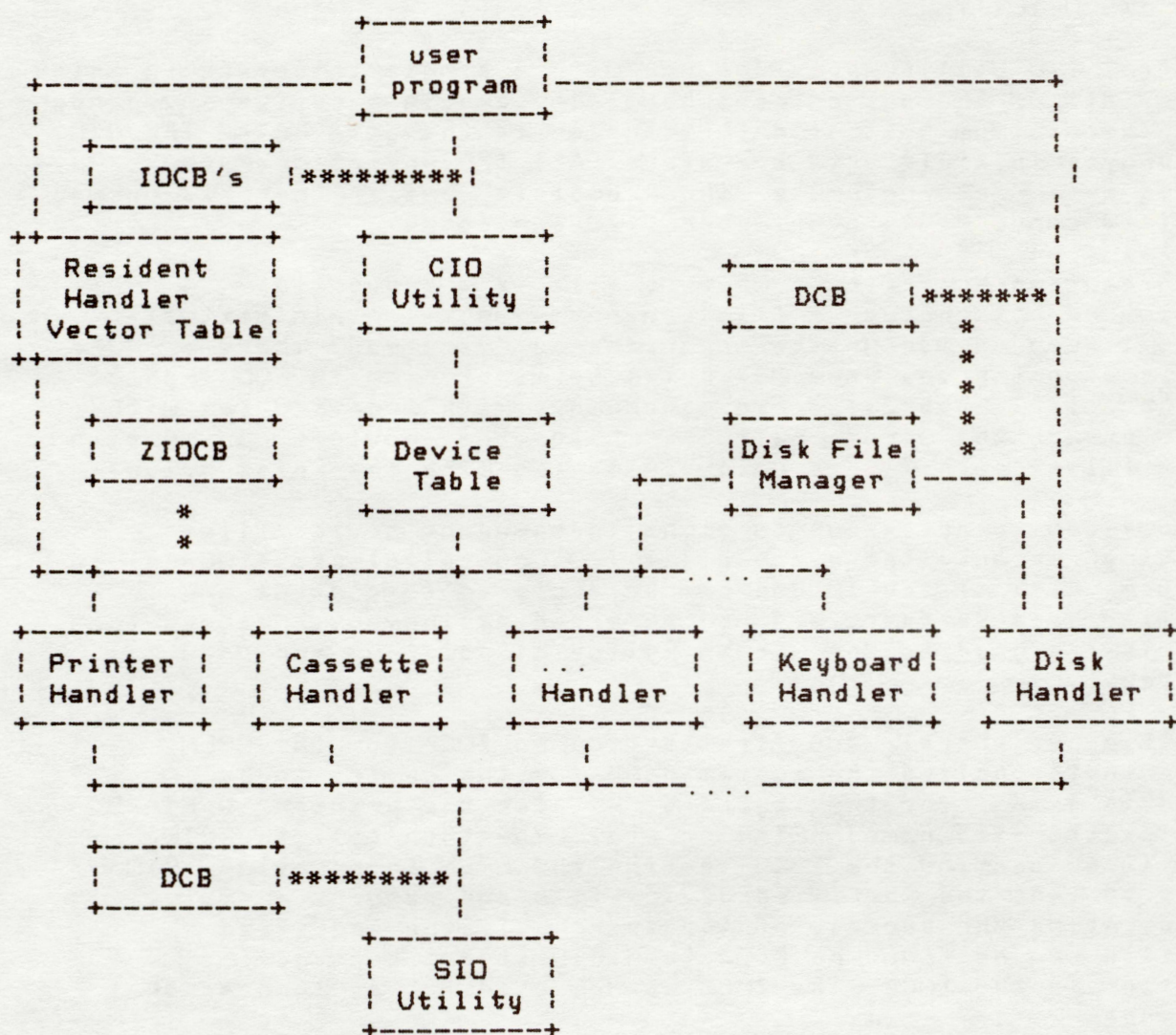
The Display Handler interprets the variable APPMHI '[000E]' to contain the address below which MEMTOP cannot extend. This allows you to protect the portion of free memory space that you are using from being overwritten as a result of screen mode change. The display handler will set the screen for mode 0, update MEMTOP, and return an error status to you, if it determines that the screen memory will extend below APPMHI as a result of a screen mode change. In other cases the Display Handler effects the desired mode change and updates MEMTOP.

5 I/O SUBSYSTEM

This section discusses the I/O subsystem of the Operating System. The I/O subsystem comprises a collection of routines that allow you to access peripheral and local devices at three different levels. The CIO (Central I/O Utility), provides the highest level, device independent access to devices. The second level allows communication with the device handlers. The lowest level is the SIO (Serial I/O bus Utility) routine. Any lower level access to a device involves the direct reading and writing of the hardware registers associated with the device.

The data byte is the basic unit of input/output. A data byte can contain either "binary" (non text) information, or encoded text information. The text encoding scheme supported by the OS is called ATASCII, derived from the words "ATARI ASCII." Most ATASCII codes are the same as ASCII, with the primary deviations being the control codes. Appendix D shows the ATASCII character set, and Appendices E, F, and G show device-specific implementations for the display, keyboard, and printer.

The structure of the I/O subsystem is shown on the following page.



Where: ---- shows a control path. **** shows the data structure required for a path.

Note the following:

- o The Keyboard/Display/Screen Editor Handlers don't use SIO.
- o The Diskette handler cannot be called directly from CIO.
- o The DCB is shown twice in the diagram.

Figure 5-1 I/O Subsystem Structure Flow Diagram

CENTRAL I/O UTILITY

The Central I/O Utility provides you with a single interface in which to access all of the system peripheral devices in a device-independent manner. The minimum unit of data transfer is the data byte. The CIO also supports multiple byte transfers. All I/O operations are performed on a "return-to-user-when-complete" basis; there is no way to initiate concurrent "overlapped" I/O processes.

I/O is organized by "files," where a file is a sequential collection of data bytes. A file can or may not contain textual data and it can or may not be organized by "records," where a record is a contiguous group of bytes terminated by an EOL (End of Line) character. Some files are synonymous with a device (as with the printer and the Screen Editor), while other devices can contain multiple files, each with a unique name (as with the disk drive).

CIO allows you to access up to eight independent device/files at one time, because there are eight I/O Control Blocks (IOCB's) in the system. Each of the IOCB's can be assigned to control any device/file because there are no preferred assignments, except that IOCB #0 is assigned to the Screen Editor at power-up and system reset.

To access a peripheral, you first set up an IOCB for the OPEN command, that supplies the system name for the device to be accessed (e.g. K:, for the keyboard, P:, for the printer, D: STARS for a diskette file named 'STARS', etc). You then call the CIO, telling it to examine the IOCB to find the OPEN information. CIO attempts to find the specified device/file and returns a status byte indicating the success of the search. If the specified device/file can be found by CIO, then CIO stores control information in the IOCB. The IOCB is now used for as long as that file is open.

Once a file is open, it can then be accessed using data-read or data-write types of commands; in general, reading can proceed until there is no more data to read (End of File) and writing can proceed until there is no more medium to store data on (End of Medium), although neither reading nor writing need proceed to that point. The reading and writing of data generally occurs into and out of user-supplied data buffers (although a special case allowing single byte transfers using the 6502 A register is provided).

When there are no more accesses to be performed on an open device/file, you perform the close operation. This accomplishes two functions:

- o It terminates and makes permanent an output file (essential for diskette and cassette).
- o It releases that IOCB to be used for another I/O operation.

CIO Design Philosophy

The CIO utility was designed specifically to meet the following design criteria.

- o The transfer of data is device independent.
- o Byte-at-a-time, multiple byte and record-aligned accesses are supported.
- o Multiple device/files can be accessed concurrently.
- o Error handling is largely device independent.
- o New device handlers can be added without altering the system ROM.

Device Independence

CIO provides device independence by having a single entry point for all devices (and for all operations) and by having a device-independent calling sequence. Once a device/file is opened, data transfers occur with no regard to the actual device involved. Uniform rules for handling byte- and record-oriented data transfers allow the actual device storage block sizes to be transparent to you.

Data Access Methods

The CIO supports two file access methods: byte-aligned and record-aligned.

Byte-aligned accesses allow you to treat the device/file as a sequential byte stream; any number of bytes can be read or written and the following operation will continue where the prior one left off. Records are of no consequence in this mode, and reads or writes can encompass multiple records if desired.

Record-aligned accesses allow you to deal with the data stream at a higher level, that of the data record or "line of text." Each and every write operation creates a single record (by definition). Each read operation assures that the following read operation will start at the beginning of a record. Record-aligned accesses cannot deal with portions of more than one record at a time. Record-aligned accesses are useful only with text data or with binary data guaranteed not to contain the EOL character (\$9B) as data.

Note that any file can be accessed using the byte-aligned access method, regardless of how the file was created. But not all files can be successfully read using record-aligned accesses; the file

must contain EOL characters at the end of each record and at no other place.

Multiple Device/File Concurrency

Up to eight device/files can be accessed concurrently using CIO, each operating independently of the others.

Unified Error Handling

All error detection and recovery occurs within the CIO subsystem. The status information that reaches you is in the form of a status byte for each device/file. Error codes are device independent as much as possible (see Appendix B).

Device Expansion

Devices are known by single character names such as K or P, and a number of device handlers are part of the resident system ROM. However, additional device handlers can be added to the system using the RAM-resident device table; this is normally done at power-up time as with the diskette boot process, but can be done at any point in time.

CIO Calling Mechanism

The input/output control block (IOCB) is the primary parameter passing structure between you and CIO. There are eight IOCB's in the system, arranged linearly in RAM as shown below:

```
+-----+ low address [0340]
| IOCB 0 |
+-----+
| IOCB 1 |
+-----+
=       =
+-----+
| IOCB 6 |
+-----+
| IOCB 7 |
+-----+ high address
```

Figure 5-2 CIO Calling Mechanism

One IOCB is required for each open device/file. Any IOCB can be used to control any device/file, although IOCB 0 is normally assigned to the Screen Editor (E:). You perform a typical I/O operation by:

- o Inserting appropriate parameters into an IOCB of your choosing
- o Putting the IOCB number times 16 into the 6502 X register
- o Performing a JSR to the CIO entry point CIOV [E456].

CIO returns to you when the operation is complete or if an error was encountered. The operation status is in the IOCB used, as well as in the 6502 Y register. The 6502 condition codes will also reflect the value in the Y register. In some cases a data byte will be in the 6502 A register. The X register will remain unchanged for all operations and conditions. An example is shown below:

```
IOCB2X = $20          ; INDEX FOR IOCB #2.

      LDX      #IOCB2X
      JSR      CIOV
      CPY      #0      ; (optional)
      BMI      ERROR
```

This sector describes each IOCB byte, with its file name and address. Each IOCB is 16 bytes long. Some bytes can be altered by you and some are reserved for use by CIO and/or the device handlers.

Handler ID -- ICHID [0340]

The handler ID is an index into the system device table (see Section 9) and is not user-alterable. This byte is set by CIO as the result of an OPEN command and is left unchanged until the device/file is closed, at that time CIO will set the byte to \$FF.

Device Number -- ICDNO [0341]

The device number is provided by CIO as the result of an OPEN command and is not user-alterable. This byte is used to distinguish between multiple devices of the same type, such as D1: and D2:.

Command Byte -- ICCMD [0342]

You set the command byte. It specifies the command to be performed by the CIO. This byte is not altered by CIO.

Status -- ICSTA [0343]

The CIO conveys operation status to you with the command status byte as a result of each and every CIO call. Each and every CIO call updates the command status byte. The most significant (sign) bit is a one for error conditions and zero for non-error conditions, and the remaining bits represent an error number. See Appendix B for a list of status codes.

Buffer Address -- ICBAL [0344] and ICBAH [0345]

You set this 2-byte pointer; it is not altered by CIO. The pointer contains the address of the beginning (low address) of a buffer that:

- o Contains data for read and write operations
- o Contains the device/filename specification for the OPEN command.

You can alter the pointer at any time.

PUT Address -- ICPTL [0346] and ICPTH [0347]

The CIO sets this 2-byte pointer at OPEN time to the handler's PUT CHARACTER entry point (- 1). The pointer was provided to accommodate the people writing the ATARI BASIC cartridge, and has no legitimate use in the system. This variable is set to point to CIO's "IOCB not OPEN" routine on CLOSE, Power-up and [SYSTEM.RESET].

Buffer Length/Byte Count -- ICBLL [0348] and ICBLH [0349]

You set this 2-byte count to indicate the size of the data buffer pointed to by ICBAL and ICBAH for read and write operations. It is not required for OPEN. After each read or write operation, CIO will set this parameter to the number of bytes actually transferred into or out of the data buffer. For record-aligned access, the record length can well be less than the buffer length. Also an end of file condition or an error can cause the byte count to be less than the buffer length.

Auxiliary Information -- ICAX1 [034A] and ICAX2 [034B]

You set these 2-bytes. They contain information that is used by the OPEN command process and/or is device-dependent.

For OPEN, two bits of ICAX1 are always used to specify the OPEN direction as shown below, where R is set to 1 for input (read) enable and W is set to 1 for output (write) enable.

```

      7      3 2 0
+---+---+---+---+
| | | | |W|R| | |
+---+---+---+---+
```

ICAX1 is not altered by CIO. You should not alter ICAX1 once the device/file is open.

The remaining bits of ICAX1 and all of ICAX2 contain only device-dependent data and are explained later in this section.

Remaining Bytes (ICAX3-ICAX6)

The handler reserves the four remaining bytes for processing the I/O command for CIO. There is no fixed use for these bytes. They are not user-alterable except as specified by the particular device descriptions. These bytes will be referred to as ICAX3, ICAX4, ICAX5 and ICAX6, although there are no equates for those names in the OS equate file.

CIO Functions

The CIO supports records and blocks and the handlers support single bytes. All of the system handlers support one or more of the eight basic functions subject to restrictions based upon the direction of data transfer (e.g. one cannot read data from the printer). The basic functions are: OPEN, CLOSE, GET CHARACTERS, PUT CHARACTERS, GET RECORD, PUT RECORD, GET STATUS, and SPECIAL.

OPEN -- Assign Device/Filename to IOCB and Ready for Access

A device/file must be opened before it can be accessed. This process links a specific IOCB to the appropriate device handler, initializes the device/file, initializes all CIO control variables, and passes device-specific options to the device handler.

You set up the following IOCB parameters prior to calling CIO for an OPEN operation:

COMMAND BYTE = \$03

BUFFER ADDRESS = pointer to a device/filename specification.

AUX1 = OPEN direction bits, plus device-dependent information.

AUX2 = device-dependent information.

After an OPEN operation, CIO will have altered the following IOCB parameters:

HANDLER ID = index to the system device table; this is used only by CIO and must not be altered.

DEVICE NUMBER = device number taken from the device/filename specification and must not be altered.

STATUS = result of OPEN operation; see Appendix B for a list of the possible status codes. In general, a negative status will indicate a failure to open properly.

PUT ADDRESS = pointer to the PUT CHARACTERS routine for the device handler just opened.

It is recommended that this pointer not be used.

CLOSE -- Terminate Access to Device/File and Release IOCB.

You issue a CLOSE command after you are through accessing a given device/file. The CLOSE process completes any pending data writes, goes to the device handler for any device-specific actions, and then releases the IOCB.

You set the following IOCB parameter prior to calling CIO:

COMMAND BYTE = \$0C

The CIO alters the following IOCB parameters as a result of the CLOSE operation:

HANDLER ID = \$FF

STATUS = Result of CLOSE operation.

PUT ADDRESS = pointer to "IOCB not OPEN" routine.

GET CHARACTERS -- Read n Characters (Byte-Aligned Access)

The specified number of characters are read from the device/file to the user-supplied buffer. EOL characters have no termination features when using this function; there can be no EOL, or many EOL's, in the buffer after operation completion. There is a special case provided that passes a single byte of data in the 6502 A register when the buffer length is set to zero.

You set the following IOCB parameters prior to calling CIO:

COMMAND BYTE = \$07

BUFFER ADDRESS = pointer to data buffer.

BUFFER LENGTH = number of bytes to read; if this is zero, the data will be returned in the 6502 A register only.

The CIO alters the following IOCB parameters as a result of the GET CHARACTERS operation:

STATUS = result of GET CHARACTERS operation.

BYTE COUNT/BUFFER LENGTH = number of bytes read to the buffer. The BYTE COUNT will always equal the BUFFER LENGTH except when an error or an end-of-file condition occurs.

PUT CHARACTERS -- Write n Characters (Byte-Aligned Access)

The specified number of characters are written from the user-supplied buffer to the device/file. EOL characters have no buffer terminating properties, although they have their standard meaning to the device/file receiving them; no EOL's are generated by CIO. There is a special case that allows a single character to be passed to CIO in the 6502 A register if the buffer length is zero.

You set the following IOCB parameters prior to initiating the PUT CHARACTERS operation:

COMMAND BYTE = \$0B

BUFFER ADDRESS = pointer to data buffer.

BUFFER LENGTH = number of bytes of data in buffer.

The CIO alters the following IOCB parameter as a result of the PUT CHARACTERS operation:

STATUS = result of PUT CHARACTERS operation.

GET RECORD -- Read Up To n Characters (Record-Aligned Access)

Characters are read from the device/file to the user-supplied buffer until either the buffer is full or an EOL character is read and put into the buffer. If the buffer fills before an EOL is read, then the CIO continues reading characters from the device/file until an EOL is read,, and sets the status to indicate that a truncated record was read. No EOL will be put at the end of the buffer.

You set the following IOCB parameters prior to calling CIO:

COMMAND BYTE = \$05

BUFFER ADDRESS = pointer to data buffer.

BUFFER LENGTH = maximum number of bytes to read (including the EOL character).

The CIO alters the following IOCB parameters as a result of the GET RECORD operation:

STATUS = result of GET RECORD operation.

BYTE COUNT/BUFFER LENGTH = number of bytes read to data buffer; this can be less than the maximum buffer length.

PUT RECORD -- Write Up To n Characters (Record-Aligned Access)

Characters are written from the user-supplied buffer to the device/file until either the buffer is empty or an EOL character is written. If the buffer is emptied without writing an EOL character to the device/file, then CIO will send an EOL after the last user-supplied character.

You set the following IOCB parameters prior to calling CIO:

COMMAND BYTE = \$09

BUFFER ADDRESS = pointer to data buffer.

BUFFER LENGTH = maximum number of bytes in buffer.

The CIO alters the following IOCB parameter as a result of the PUT RECORD operation:

STATUS = result of PUT RECORD operation.

GET STATUS -- Return Device-Dependent Status Bytes

The device controller is sent a STATUS command, and the controller returns four bytes of status information that are stored in DVSTAT [02EA].

You set the following IOCB parameters prior to calling CIO:

COMMAND BYTE = \$0D

BUFFER ADDRESS = pointer to a device/filename specification if the IOCB is not already OPEN; see the discussion of the implied OPEN option below.

After a GET STATUS operation, CIO will have altered the following parameters:

STATUS = result of GET STATUS operation; see Appendix B for a list of the possible status codes.

DVSTAT = the four-byte response from the device controller.

SPECIAL -- Special Function

Any command byte value greater than \$0D is treated by CIO as a special case. Since CIO does not know what the function is, CIO transfers control to the device handler for complete processing of the operation.

The user sets the following IOCB parameters prior to calling CIO:

COMMAND BYTE > \$0D

BUFFER ADDRESS = pointer to a device/filename specification if the IOCB is not already open; see the discussion of the implied OPEN option below.

Other IOCB bytes can be set up, depending upon the specific SPECIAL command being performed.

After a SPECIAL operation, CIO will have altered the following parameters:

STATUS = result of SPECIAL operation; see Appendix B for a list of the possible status codes.

Other bytes can be altered, depending upon the specific SPECIAL command.

Implied OPEN Option

The GET STATUS and SPECIAL commands are treated specially by CIO; they can use an already open IOCB to initiate the process or they can use an unopened IOCB. If the IOCB is unopened, then the buffer address must contain a pointer to a device/filename specification, just as for the OPEN command; CIO will then open that IOCB, perform the specified command and then close the IOCB again.

Device/Filename Specification

As part of the OPEN command, the IOCB buffer address parameter points to a device/filename specification, that is a string of ATASCII characters in the following format:

<specification> ::= <device>[<number>]:[<filename>]<eol>

<device> ::= C|D|E|K|P|R|S

<number> ::= 1|2|3|4|5|6|7|8

<filename> has device-dependent characteristics.

<eol> ::= \$9B

The following devices are supported at this writing:

C = Cassette drive

D1 through D8 = Floppy diskette drives *

E = Screen Editor

K = Keyboard

P = 40-column printer

P2 = 80-column printer *

R1 through R4 = RS-232-C interfaces *

S = Screen display

Devices flagged by asterisks (*) are supported by nonresident handlers.

If <number> is not specified, it is assumed to be 1.

The following examples show valid device/filename specifications:

C:	Cassette
D2:BDAT	File "BDAT" on disk drive #2
D:HOLD	File "HOLD" on disk drive #1
K:	Keyboard

I/O Example

The example provided in this section illustrates a simple example of an I/O operation using the CIO routine.

```
; This code segment illustrates the simple example of reading
; text lines (records) from a diskette file named TESTER on disk
; drive #1. All symbols used are equated within the program
; although many of the symbols are in the OS equate file.
```

```
; The program performs the following steps:
```

- ```
;
; 1. Opens the file 'D1:TESTER' using IOCB #3.
; 2. Reads records until an error or EOF is reached.
; 3. Closes the file.
```

```
; I/O EQUATES
```

```
EOL= $9B ; END OF LINE CHARACTER.
IOCB3= $30 ; IOCB #3 OFFSET (FROM IOCB #0).

ICHID= $0340 ; (HANDLER ID -- SET BY CIO).
ICDNO= ICHID+1 ; (DEVICE # -- SET BY CIO).
ICCOM= ICDNO+1 ; COMMAND BYTE.
ICSTA= ICCOM+1 ; STATUS BYTE -- SET BY CIO.
ICBAL= ICSTA+1 ; BUFFER ADDRESS (LOW).
ICBAH= ICBAL+1 ; BUFFER ADDRESS (HIGH).
ICPTL= ICBAH+1
ICPTH= ICPTL+1
ICBLL= ICPTH+1 ; BUFFER LENGTH (LOW).
ICBLH= ICBLL+1 ; BUFFER LENGTH (HIGH).
ICAX1= ICBLH+1 ; AUX 1.
ICAX2= ICAX1+1 ; AUX 2.

OPEN= $03 ; OPEN COMMAND.
GETREC= $05 ; GET RECORD COMMAND.
CLOSE= $0C ; CLOSE COMMAND.

OREAD= $04 ; OPEN DIRECTION = READ.
OWRIT= $08 ; OPEN DIRECTION = WRITE.

EOF= $88 ; END OF FILE STATUS VALUE.

CIOV= $E456 ; CIO ENTRY VECTOR ADDRESS.
```

```
;
; FIRST INITIALIZE THE IOCB FOR FILE "OPEN".
;
```

```
LDX #IOCB3 ; SETUP TO ACCESS IOCB #3.
```

```

LDA #OPEN ; SETUP OPEN COMMAND.
STA ICCOM, X

LDA #NAME ; SETUP BUFFER POINTER TO ...
STA ICBAL, X ; ... POINT TO FILENAME.
LDA #NAME/256
STA ICBAH, X

LDA #OREAD ; SETUP FOR OPEN READ.
STA ICAX1, X

LDA #0 ; CLEAR AUX 2.
STA ICAX2, X

```

```

;
; "OPEN" THE FILE.
;

```

```

JSR CIOV ; PERFORM "OPEN" OPERATION.
BPL TP10 ; STATUS WAS POSITIVE -- OK.

JMP ERROR ; NO -- "OPEN" PROBLEM.

```

```

;
; SETUP TO READ A RECORD.
;

```

```

TP10 LDA #GETREC ; SETUP "GET RECORD" COMMAND.
 STA ICCOM, X

 LDA #BUFF ; SETUP DATA BUFFER POINTER.
 STA ICBAL, X
 LDA #BUFF/256
 STA ICBAH, X

```

```

;
; READ RECORDS.
;

```

```

LOOP LDA #BUFFSZ ; SETUP MAX RECORD SIZE ...
 STA ICBLL, X ; ... PRIOR TO EVERY READ.
 LDA #BUFFSZ/256
 STA ICBLH, X

 JSR CIOV ; READ A RECORD.
 BMI TP20 ; MAY BE END OF FILE.

```

```

;
; A RECORD IS NOW IN THE DATA BUFFER "BUFF". IT IS TERMINATED BY

```

```

; AN EOL CHARACTER, AND THE RECORD LENGTH IS IN "ICBLL" and "ICBLH".
; THIS EXAMPLE WILL DO NOTHING WITH THE RECORD JUST READ.
;

```

```

 JMP LOOP ; READ NEXT RECORD.

```

```

;
; NEGATIVE STATUS ON READ -- CHECK FOR END OF FILE.
;

```

```

TP20 CPY #EOF ; END OF FILE STATUS?
 BNE ERROR ; NO -- ERROR.

 LDA #CLOSE ; YES -- CLOSE FILE.
 STA ICCOM, X

 JSR CIOV ; CLOSE THE FILE.

 JMP * ; *** END OF PROGRAM ***

```

```

;
; DATA REGION OF EXAMPLE PROGRAM
;

```

```

NAME .BYTE "D1:TESTER",EOL

```

```

BUFFSZ= 80 ; 80 CHARACTER RECORD MAX
 (INCLUDES EOL).

```

```

BUFF= * ; READ BUFFER.
*= *+BUFFSZ
 .END

```

Figure 5-3 An I/O Example

## Device-Specific Information

This section provides device-specific information regarding the device handlers that interface to CIO.

### Keyboard Handler (K:)

The keyboard device is a read only device with a handler that supports the following CIO functions:

- OPEN
- CLOSE
- GET CHARACTERS
- GET RECORD
- GET STATUS (null function)

The Keyboard Handler can produce the following error statuses:

- \$80 -- [BREAK] key abort.
- \$88 -- end-of-file (produced by pressing [CTRL] 3).

The Keyboard Handler is one of the resident handlers. It has a set of device vectors starting at location E420.

The keyboard can produce any of the 256 codes in the ATASCII character set (see Appendix F). Note that a few of the keyboard keys do not generate data at the Keyboard Handler level. These keys are described below:

- [/!\] - The ATARI key toggles a flag that enables/disables the inversion of bit 7 of each data character read. The Screen Editor editing keys are exempted from such inversion, however.

CAPS - The [CAPS/LOWR] key provides three functions:

- [SHIFT][CAPS/LOWR] -- Alpha caps lock.
- [CNTRL][CAPS/LOWR] -- Alpha [CTRL] lock.
- [CAPS/LOWR] -- Alpha unlock.

The system powers up and will system reset to the alpha caps lock option.

Some key combinations are ignored by the handler, such as [CTRL] 4 through [CTRL] 9, [CTRL] 0, [CTRL] 1, [CTRL] /, and all key combinations in that the [SHIFT] and [CTRL] keys are depressed simultaneously.

The [CTRL] 3 key generates an EOL character and returns EOF status.

The [BREAK] key generates an EOL character and returns BREAK status.

### CIO Function Descriptions

The device-specific characteristics of the standard CIO functions (described earlier in this section) are detailed below:

#### OPEN

The device name is K, and the handler ignores any device number and filename specification, if included.

There are no device-dependent option bits in AUX1 or AUX2.

#### CLOSE

No special handler actions.

#### GET CHARACTERS and GET RECORD

The handler returns the ATASCII key codes to CIO as they are entered, with no facility for editing.

#### GET STATUS

The handler does nothing but set the status to \$01.

### Theory of Operation

Pressing a keyboard key generates an IRQ interrupt and vectors to the Keyboard Handler's interrupt service routine (see Section 6). The key code for the key pressed is then read and stored in data base variable CH [02FC]. This occurs whether or not there is an active read request to the Keyboard Handler, and effects a one-byte FIFO for keyboard entry. See Appendix L (E8) for a discussion of the auto repeat feature.

The Keyboard Handler monitors the CH variable for not containing the value \$FF (empty state) whenever there is an active read request for the handler. When CH shows nonempty, the handler takes the key code from CH and sets CH to \$FF again. The key code byte obtained from CH is not an ATASCII code and has the following form:

```

 7 0
+---+---+---+---+---+
!C!S! key code !
+---+---+---+---+---+

```

Where: C = 1 if the [CTRL] key is pressed.  
 S = 1 if the [SHIFT] key is pressed.

The remaining six bits are the hardware key code.

The key code obtained is then converted to ATASCII using the first of the following rules that applies:

1. Ignore the code if the C and S bits are both set.
2. If the C bit is set, process the key as a [CTRL] code.
3. If the S bit is set, process the key as a [SHIFT] code.
4. If [CTRL] lock is in effect, process alpha characters as CTRL codes, all others as lowercase.
5. IF [SHIFT] lock is in effect, process alpha characters as SHIFT codes, all others as lowercase.
6. Else, process as lowercase character.

Then: If the resultant code is not a Screen Editor control code, and if the video inverse flag is set, then set bit 7 of the ATASCII code (will cause inverse video when displayed).

# KEY CODE TO ATASCII CONVERSION TABLE

| Key Code | Key Cap | Lwr. Case | [SHIFT] | [CTRL] | Key Code | Key Cap | Lwr. Case | SHIFT | CTRL |
|----------|---------|-----------|---------|--------|----------|---------|-----------|-------|------|
| 00       | L       | 6C        | 4C      | 0C     | 20       | ,       | 2C        | 5B    | 00   |
| 01       | J       | 6A        | 4A      | 0A     | 21       | SPACE   | 20        | 20    | 20   |
| 02       | ;       | 3B        | 3A      | 7B     | 22       | .       | 2E        | 5D    | 60   |
| 03       | --      | --        | --      | --     | 23       | N       | 6E        | 4E    | 0E   |
| 04       | --      | --        | --      | --     | 24       | --      | --        | --    | --   |
| 05       | K       | 6B        | 4B      | 0B     | 25       | M       | 6D        | 4D    | 0D   |
| 06       | +       | 2B        | 5C      | 1E     | 26       | /       | 2F        | 3F    | --   |
| 07       | *       | 2A        | 5E      | 1F     | 27       | /!\     | --        | --    | --   |
| 08       | O       | 6F        | 4F      | 0F     | 28       | R       | 72        | 52    | 12   |
| 09       | --      | --        | --      | --     | 29       | --      | --        | --    | --   |
| 0A       | P       | 70        | 50      | 10     | 2A       | E       | 65        | 45    | 05   |
| 0B       | U       | 75        | 55      | 15     | 2B       | Y       | 79        | 59    | 19   |
| 0C       | RET     | 9B        | 9B      | 9B     | 2C       | TAB     | 7F        | 9F    | 9E   |
| 0D       | I       | 69        | 49      | 09     | 2D       | T       | 74        | 54    | 14   |
| 0E       | -       | 2D        | 5F      | 1C     | 2E       | W       | 77        | 57    | 17   |
| 0F       | =       | 3D        | 7C      | 1D     | 2F       | Q       | 71        | 51    | 11   |
| 10       | V       | 76        | 56      | 16     | 30       | 9       | 39        | 28    | --   |
| 11       | --      | --        | --      | --     | 31       | --      | --        | --    | --   |
| 12       | C       | 63        | 43      | 03     | 32       | O       | 30        | 29    | --   |
| 13       | --      | --        | --      | --     | 33       | 7       | 37        | 27    | --   |
| 14       | --      | --        | --      | --     | 34       | BACKS   | 7E        | 9C    | FE   |
| 15       | B       | 62        | 42      | 02     | 35       | 8       | 38        | 40    | --   |
| 16       | X       | 78        | 58      | 18     | 36       | <       | 3C        | 7D    | 7D   |
| 17       | Z       | 7A        | 5A      | 1A     | 37       | >       | 3E        | 9D    | FF   |
| 18       | 4       | 34        | 24      | --     | 38       | F       | 66        | 46    | 06   |
| 19       | --      | --        | --      | --     | 39       | H       | 68        | 48    | 08   |
| 1A       | 3       | 33        | 23      | 9B*    | 3A       | D       | 64        | 44    | 04   |
| 1B       | 6       | 36        | 26      | --     | 3B       | --      | --        | --    | --   |
| 1C       | [ESC]   | 1B        | 1B      | 1B     | 3C       | CAPS    | --        | --    | --   |
| 1D       | 5       | 35        | 25      | --     | 3D       | G       | 67        | 47    | 07   |
| 1E       | 2       | 32        | 22      | FD     | 3E       | S       | 73        | 53    | 13   |
| 1F       | 1       | 31        | 21      | --     | 3F       | A       | 61        | 41    | 01   |

\* [CTRL] 3 returns EOF status.

A complement of this table (ATASCII to keystroke) is given in Appendix F.

Figure 5-4 Keycode to ATASCII Conversion Table

### Display Handler (S:)

The display device is a read/write device with a handler that supports the following CIO functions:

- OPEN
- CLOSE
- GET CHARACTERS
- GET RECORD
- PUT CHARACTERS
- PUT RECORD
- GET STATUS (null function)
- DRAW
- FILL

The Display Handler can produce the following error statuses:

- \$B4 -- Invalid special command.
- \$BD -- Cursor out-of-range.
- \$91 -- Screen mode > 11.
- \$93 -- Not enough memory for screen mode selected.

The Display Handler is one of the resident handlers, and therefore has a set of device vectors starting at location E410.

### Screen Modes

You can operate the display screen in any of 20 configurations (modes 1 through 8, with or without split screen; plus mode 0, and modes 9 through 11 without split screen). Mode 0 is the text displaying mode. Modes 1 through 11 are all graphics modes (although modes 2 and 3 do display a subset of the ATASCII character set). Modes 9 through 11 require a GTIA chip to be installed in place of the standard CTIA chip.

### TEXT MODE 0

In text mode 0 the screen is comprised of 24 lines of 40 characters per line. Program alterable left and right margins limit the display area. They default to 2 and 39 (of a possible 0 and 39).

A program-controllable cursor shows the destination of the next character to be output onto the screen. The cursor is visible as the inverse video representation of the current character at the destination position.

The text screen data is internally organized as variable length logical lines. The internal representation is 24 lines when the screen is cleared. Each EOL marks the end of a logical line as text is sent to the screen. If more than 3 physical lines of text are sent, a logical line will be formed every 3 physical lines. The number of physical lines used to comprise a logical line (1 to 3) is always the minimum required to hold the data for that logical line.

The text screen "scrolls" upward whenever a text line at the bottom row of the screen extends past the right margin, or a text line at the bottom row is terminated by an EOL. Scrolling removes the entire logical line that starts at the top of the screen, and then moves all subsequent lines upward to fill in the void. The cursor also moves upward, if the logical line deleted exceeds one physical line.

All data going to or coming from the text screen is represented in 8-bit ATASCII code as shown in Appendix E.

## TEXT MODES 1 AND 2

In text modes 1 and 2 the screen comprises either 24 lines of 20 characters (mode 1), or 12 lines of 20 characters (mode 2). The left and right margins are of no consequence in these modes and there is no visible cursor. There are no logical lines associated with the data and in all regards these modes are treated as graphics modes by the handler.

Data going to or coming from the screen is in the form shown below:

```

7 0
+--+--+--+--+--+--+--+--+--+
! C ! D !
+--+--+--+--+--+--+--+--+--+
```

Where: C is the color/character-set select field

| C<br>Value | Color<br>(default) | Color<br>Register<br>(see<br>Appendix<br>H) | Character<br>Set<br>CHBAS=\$E0 | Character<br>Set<br>CHBAS=\$E2 |
|------------|--------------------|---------------------------------------------|--------------------------------|--------------------------------|
| 0          | green              | (PF1)                                       | ! - ?                          | [HEART] [ARROW]                |
| 1          | gold               | (PF0)                                       | ! - ?                          | [HEART] [ARROW]                |
| 2          | gold               | (PF0)                                       | @ - _                          | [DIAMOND][TRIANGLE]            |
| 3          | green              | (PF1)                                       | @ - _                          | [DIAMOND][TRIANGLE]            |
| 4          | red                | (PF3)                                       | ! - ?                          | [HEART] [ARROW]                |
| 5          | blue               | (PF2)                                       | ! - ?                          | [HEART] [ARROW]                |
| 6          | blue               | (PF2)                                       | @ - _                          | [DIAMOND][TRIANGLE]            |
| 7          | red                | (PF3)                                       | @ - _                          | [DIAMOND][TRIANGLE]            |

D is a 5-bit truncated ATASCII code that selects the specific character within the set selected by the C field. See Appendix E for the graphics representations of the characters.

Data base variable CHBAS [02F4] allows for the selection of either of two data sets. The default value of \$E0 provides the capital letters, numbers and punctuation characters; the alternate value of \$E2 provides lowercase letters and the special character graphics set.

Figure 5-5 Text Modes 1 and 2 Data Form

#### GRAPHICS MODES (Modes 3 Through 11)

The screen has varying physical characteristics for each of the graphics modes as shown in Appendix H. Depending upon the mode, a 1 to 16 color selection is available for each pixel and the screen size varies from 20 by 12 (lowest resolution) to 320 by 192 (highest resolution) pixels.

There is no visible cursor for the graphics mode output.

Data going to or coming from the graphics screen is represented as 1 to 8-bit codes as shown in Appendix H and in the GET/PUT diagrams following.

#### SPLIT-SCREEN CONFIGURATIONS

In split-screen configurations, the bottom of the screen is reserved for four lines of mode 0 text. The text region is controlled by the Screen Editor, and the graphics region is controlled by the Display handler. Two cursors are maintained in this configuration so that the screen segments can be managed independently.

To operate in split-screen mode, the Screen Editor must first be opened and then the Display Handler must be opened using a separate IOCB (with the split-screen option bit set in AUX1).

## CIO Function Descriptions

The device-specific characteristics of the standard CIO functions (described earlier in this section) are detailed below:

### OPEN

The device name is S, and the handler ignores any device number and filename specification, if included.

The handler supports the following options:

```

 7 0
 +---+---+---+---+---+
AUX1 | ICISIWIRI |
 +---+---+---+---+---+

```

Where: C = 1 indicates to inhibit screen clear on OPEN.

S = 1 indicates to set up a split-screen configuration (for modes 1 through 8 only).

R and W are the direction bits (read and write).

```

 7 0
 +---+---+---+---+---+
AUX2 | | mode | |
 +---+---+---+---+---+

```

Where: mode is the screen mode (0 through 11).

Note: If the screen mode selected is 0, then the AUX1 C and S options are assumed to be 0.

You share memory utilization with the Display Handler information. Sharing is necessary because the Display Handler dynamically allocates high address memory for use in generating the screen display, and because different amounts of memory are needed for the different screen modes. Prior to initiating an OPEN command the variable APPMHI [000E] should contain the highest address of RAM you need. The Screen handler will open the screen only if no RAM is needed at or below that address.

Upon return from a screen OPEN, the variable MEMTOP [02E5] will contain the address of the last free byte at the end of RAM memory prior to the screen-required memory.

As a result of every OPEN command, the following screen variables are altered:

The text cursor is enabled (CRSINH = 0). The tabs are set to the default settings (2 and 39). The color registers are set to the default values (shown in Appendix H).

Tabs are set at positions 7, 15, 23, 31, 39, 47, 55, 63, 71, 79, 87, 95, 103, 111, 119.

CLOSE

No special handler actions.

GET CHARACTERS and GET RECORD

Returns data in the following screen mode dependent forms, where each byte contains the data for one cursor position (pixel); there is no facility for having the handler return packed graphics data.

|                                                                                                                                                                                             |                                   |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------|
| <div style="display: flex; justify-content: space-between; width: 100%;"> <span>7</span> <span>0</span> </div> <pre> +---+---+---+---+---+---+     ATASCII     +---+---+---+---+---+ </pre> | Mode 0                            |
| <pre> +---+---+---+---+---+---+   C     D     +---+---+---+---+---+ </pre>                                                                                                                  | Modes 1, 2 -- C = color/data set. |
| <pre> +---+---+---+---+---+---+   zero   D   +---+---+---+---+---+ </pre>                                                                                                                   | D = truncated ATASCII.            |
| <pre> +---+---+---+---+---+---+   zero   D   +---+---+---+---+---+ </pre>                                                                                                                   | Modes 3, 5, 7 -- D = color.       |
| <pre> +---+---+---+---+---+---+   zero   D   +---+---+---+---+---+ </pre>                                                                                                                   | Modes 4, 6, 8 -- D = color.       |
| <pre> +---+---+---+---+---+---+   zero   D   +---+---+---+---+---+ </pre>                                                                                                                   | Modes 9, 10, 11 -- D = data.      |

Figure 5-6 Graphics Mode 3-11 GET Data Form

The cursor moves to the next position as each data byte is returned. For mode 0, the cursor will stay within the specified margins; for all other modes, the cursor ignores the margins.

## PUT CHARACTERS and PUT RECORD

The handler accepts display data in the following screen mode dependent forms; there is no facility for the handler to receive graphics data in packed form.

|       |         |                                                               |
|-------|---------|---------------------------------------------------------------|
| 7     | 0       |                                                               |
| +++++ | +++++   |                                                               |
|       | ATASCII |                                                               |
| +++++ | +++++   |                                                               |
|       |         | Mode 0                                                        |
| +++++ | +++++   |                                                               |
|       | C   D   |                                                               |
| +++++ | +++++   |                                                               |
|       |         | Modes 1,2 -- C = color/data<br>set,<br>D = truncated ATASCII. |
| +++++ | +++++   |                                                               |
|       | ?   D   |                                                               |
| +++++ | +++++   |                                                               |
|       |         | Modes 3,5,7 -- D = color.                                     |
| +++++ | +++++   |                                                               |
|       | ?   D   |                                                               |
| +++++ | +++++   |                                                               |
|       |         | Modes 4,6,8 -- D = color.                                     |
| +++++ | +++++   |                                                               |
|       | ?   D   |                                                               |
| +++++ | +++++   |                                                               |
|       |         | Modes 9,10,11 -- D = data.                                    |

Figure 5-7 Graphics Mode 3-11 PUT Data Form

NOTE: For all modes, if the output data byte equals \$9B (EOL), that byte will be treated as an EOL character; and if the output data byte equals \$7D (CLEAR) that byte will be treated as a screen-clear character.

The cursor moves to the next cursor position as each data byte is written. For mode 0, the cursor will stay within the specified margins; for all other modes, the cursor ignores the margins.

While outputting, the Display Handler monitors the keyboard to detect the pressing of the [CTRL] 1 key combination. When this occurs, the handler loops internally until that key combination is pressed again: This effects a stop/start function that freezes the screen display. Note that there is no ATASCII code associated with either the [CTRL] 1 key combination or the start/stop function. The stop/start function can be controlled only from the keyboard (or by altering database variable CH as discussed in Appendix L, E4).

## GET STATUS

No handler action except to set the status to \$01.

## DRAW

This special command draws a simulated "straight" line from the current cursor position to the location specified in ROWCRS [0054] and COLCRS [0055]. The color of the line is taken from the last character processed by the Display Handler or Screen Editor. To force the color, store the desired value in ATACHR [02FB]. At the completion of the command, the cursor will be at the location specified by ROWCRS and COLCRS.

The value for the command byte for DRAW is \$11.

## FILL

This special command fills an area of the screen defined by two lines with a specified color. The command is set up the same as in DRAW, but as each point of the line is drawn, the routine scans to the right performing the procedure shown below (in PASCAL notation):

```
WHILE PIXEL [ROW,COL] = 0 DO
 BEGIN
 PIXEL [ROW,COL] := FILDAT;
 COL := COL + 1;
 IF COL > Screen right edge THEN COL := 0
 END;
```

An example of a FILL operation is shown below:

```

 + 1
 +
+-----+
+-----+
4 +-----+
 +
 + 2
```

Where: '-' represents the fill operation.  
'+' are the line points, with '+' for the endpoints.

- 1 -- set cursor and plot point.
- 2 -- set cursor and DRAW line.
- 3 -- set cursor and plot point.
- 4 -- set fill data value, set cursor, and FILL.

FILDAT [02FD] contains the fill data, and ROWCRS and COLCRS contain the cursor coordinates of the line endpoint. The value in ATACHR [02FB] will be used to draw the line; ATACHR always contains the last data read or written, so if the steps above are followed exactly, ATACHR will not have to be modified.

The value for the command byte for FILL is \$12.

#### User-Alterable Data Base Variables

Certain functions of the Display Handler require you to examine and/or alter variables in the OS database. The following describes some of the more commonly used handler variables. (see Appendix L, B1-55, for additional descriptions).

##### Cursor Position

Two variables maintain the cursor position for the graphics screen or mode 0 text screen. ROWCRS [0054] maintains the display row number; and COLCRS [0055] maintains the display column number. Both numbers range from 0 to the maximum number of rows/columns, - 1. The cursor can be set outside of the defined text margins with no ill effect. You can read and write this region. The home position (0,0) for both text and graphics is the upper left corner of the screen.

ROWCRS is a single byte. COLCRS is maintained at 2-bytes, with the least significant byte being at the lower address.

When you alter these variables, the screen representation of the cursor will not move until the next I/O operation involving the display is performed.

##### Inhibit/Enable Visible Cursor Display

You can inhibit the display of the text cursor on the screen by setting the variable CRSINH [02F0] to any nonzero value. Subsequent I/O will not generate a visible cursor.

You can enable the display of the text cursor by setting CRSINH to zero. Subsequent I/O will then generate a visible cursor.

##### Text Margins

The text screen has user-alterable left and right margins. The OS sets these margins to 2 and 39. The variable LMARGN [0052] defines the left margin, and the variable RMARGN [0053] defines the right margin. The leftmost margin value is 0 and the

rightmost margin value is 39.

The margin values inclusively define the useable portion of the screen for all operations in that you do not explicitly alter the cursor location variables as described prior to this paragraph.

### Color Control

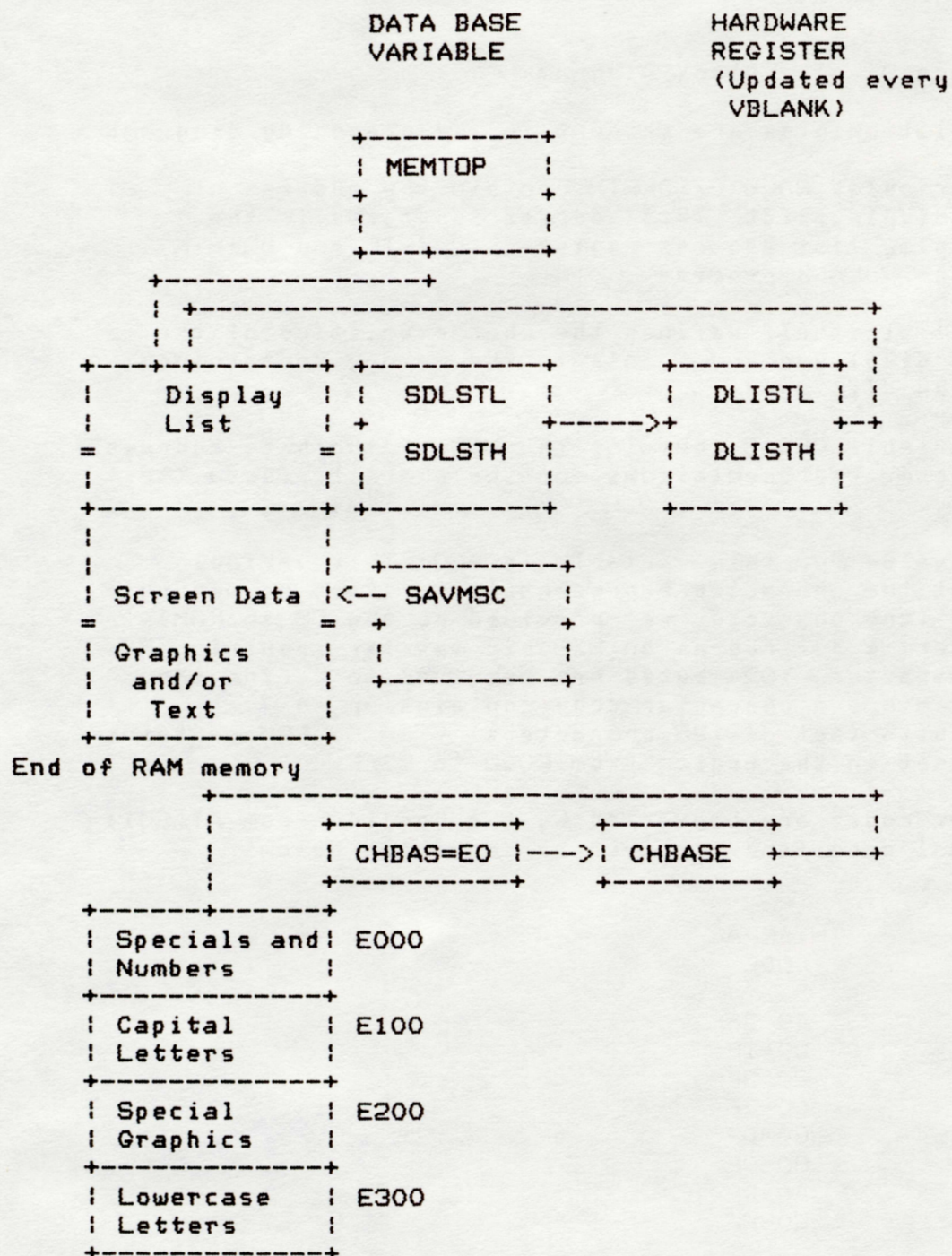
The OS updates hardware color registers using data from the OS data base as part of normal Stage 2 VBLANK processing (see Section 6). Shown below are the data base variable names, the hardware register names, and the function of each register. See Appendix H for the mode dependent uses for the registers.

| Data Base | Hardware | Function                     |
|-----------|----------|------------------------------|
| COLOR0    | COLPFO   | PFO -- Playfield 0.          |
| COLOR1    | COLPF1   | PF1 -- Playfield 1.          |
| COLOR2    | COLPF2   | PF2 -- Playfield 2.          |
| COLOR3    | COLPF3   | PF3 -- Playfield 3.          |
| COLOR4    | COLBK    | BAK -- Playfield background. |
| PCOLOR0   | COLPM0   | PM0 -- Player/missile 0.     |
| PCOLOR1   | COLPM1   | PM1 -- Player/missile 1.     |
| PCOLOR2   | COLPM2   | PM2 -- Player/missile 2.     |
| PCOLOR3   | COLPM3   | PM3 -- Player/missile 3.     |

### Theory of Operation

The Display Handler automatically sets up all memory resources required to create and maintain the screen display at OPEN time. The screen generation hardware requires that two distinct data areas exist for graphics modes: 1) a display list and 2) a screen data region. A third data area must exist for text modes. This data area defines the screen representation for each of the text characters. Consult the ATARI Home Computer Hardware Manual for a complete understanding of the material that is to follow.

The simplified block diagram below shows the relationships between the memory and hardware registers used to set up a screen display (without player/missile graphics) by the OS Note that the hardware registers allow for many other possibilities.



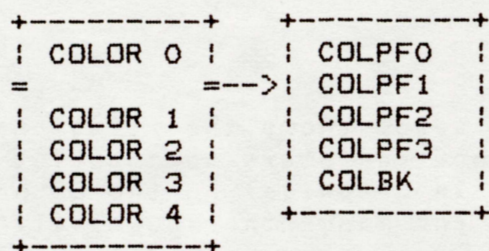


Figure 5-8 Screen Display Block Diagram

The following relationships are present in the preceding diagram:

1. Data base variables SDLSTL/SDLSTH contain the address of the current display list. This address is stored in the hardware display list address registers DLISTL and DLISTH as part of the VBLANK process.
2. The display list itself defines the characteristics of the screen to be displayed and points to the memory containing the data to be displayed.
3. Data base variable CHBAS contains the MSB of the base address of the character representations for the character data (text modes only).

The default value for this variable is \$E0. This variable declares that the character representations start at memory address E000 (the character set provided by the OS in ROM). Each character is defined as an 8x8 bit matrix, requiring 8 bytes per character. 1024 bytes are required to define the largest set, since a character code contains up to 7 significant bits (set of 128 characters). The OS ROM contains the default set in the region from E000 to E3FF.

All character codes are converted by the handler from ATASCII to an internal code (and vice versa), as shown below:

| ATASCII<br>CODE | INTERNAL<br>CODE |
|-----------------|------------------|
| 00-1F           | 40-5F            |
| 20-3F           | 00-1F            |
| 40-5F           | 20-3F            |
| 60-7F           | 60-7F            |
| 80-9F           | C0-DF            |
| A0-BF           | 80-9F            |
| C0-DF           | A0-BF            |
| E0-FF           | E0-FF            |

The character set in ROM is ordered by internal code order. Three considerations differentiate the internal code from the external (ATASCII) code:

ATASCII codes for all but the special graphics characters were to be similar to ASCII. The alphabetic, numeric, and punctuation character codes are identical to ASCII.

In text modes 1 and 2 it was desired that one character subset include capital letters, numbers, and punctuation and the other character subset include lowercase letters and special graphics characters.

The codes for the capital and lowercase letters were to be identical in text modes 1 and 2.

Database variables COLOR0 through COLOR4 contain the current color register assignments. Hardware color registers receive these values as part of the stage 1 VBLANK process, thus providing synchronized color changes (see Appendix H).

Database variable SAVMSC points to the lowest memory address of the screen data region. It corresponds to the data displayed at the upper left corner of the display.

When the Display Handler receives an open command, it first determines the screen mode from the OPEN IOCB. Then it allocates memory from the end of RAM downward (as specified by data base variable RAMTOP), first for the screen data and then for the display list. The screen data region is cleared and the display list is created if sufficient memory is available. The display list address is stored to the database.

## Screen Editor (E:)

The Screen Editor is a read/write handler that uses the Keyboard Handler and the Display Handler to provide "line-at-a-time" input with interactive editing functions, as well as formatted output.

The Screen Editor supports the following CIO functions:

- OPEN
- CLOSE
- GET CHARACTERS
- GET RECORD
- PUT CHARACTERS
- PUT RECORD
- GET STATUS (null function)

See Keyboard Handler and Display Handler Sections for a discussion of Screen Editor error statuses.

The Screen Editor is one of the resident handlers, and therefore has a set of device vectors starting at location E400.

The Screen Editor is a program that reads key data from the Keyboard Handler and sends each character to the Display Handler for immediate display. The Screen Editor also accepts data from you to send to the Display Handler, and reads data from the Display Handler (not the Keyboard Handler) for you. In fact, the Keyboard Handler, Display Handler, and the Screen Editor are all contained in one monolithic hunk of code.

Most of the behaviors already defined for the Keyboard Handler and the Display Handler apply as well to the Screen Editor: The discussions in this Section will be limited to deviations from those behaviors, or to additional features that are part of the Screen Editor only. The Screen Editor deals only with text data (screen mode 0). This Section also explains the split-screen configuration feature.

The Screen Editor uses the Display Handler to read data from graphics and text screens on demand. You use the Screen Editor to determine when the program will read Screen data, and where upon the screen the data will be read from. You first locates the cursor on the screen to determine the screen area to be read; you then press the [RETURN] key to determine when the program will begin to read the data indicated.

When the [RETURN] key is pressed, the entire logical line within that the cursor resides is then made available to the calling program. Trailing blanks in a logical line are never returned as data, however. After all of the data in the line has been sent to the caller (this can entail multiple READ CHARACTERS functions if desired), an EOL character is returned and the cursor is positioned to the beginning of the logical line following the one just read.

## CIO Function Descriptions

The device-specific characteristics of the standard CIO functions are detailed below:

### OPEN

The device name is E, and the Screen Editor ignores any device number and filename specification, if included.

The Screen Editor supports the following option:

```

 7 0
 +---+---+---+---+---+
AUX1 | |W|R| |F|
 +---+---+---+---+---+

```

Where: R and W are the direction bits (read and write).

F = 1 indicates that a "forced read" is desired (see GET CHARACTER and GET RECORD for more information).

### CLOSE

No special handler actions.

### GET CHARACTER and GET RECORD

Normally the Screen Editor will return data only when you press the [RETURN] key at the keyboard. However, the "forced read" OPEN option allows you to read text data without intervention. When you command a READ operation, the Screen Editor will return data from the start of the logical line in which the text cursor is located, and then move the cursor to the beginning of the following logical line. A read of the last logical line on the screen will cause the screen data to scroll.

A special case occurs when characters are output without a terminating EOL, and then additional characters are appended to

that logical line from the keyboard. When the [RETURN] key is pressed, only the keyboard entered characters are sent to the caller, unless the cursor has been moved out of and then back into the logical line, in that case all of the logical line will be sent.

#### PUT CHARACTER and PUT RECORD

The Handler accepts ATASCII characters as one character per byte. Sixteen of the 256 ATASCII characters are control codes; the EOL code has universal meaning, but most of the other control codes have special meaning only to a display or print device. The Screen Editor processing of the ATASCII control codes is explained below:

**CLEAR (\$7D)** -- The Screen Editor clears the current display of all data and the cursor is placed at the home position (upper left corner of the screen).

**CURSOR UP (\$1C)** -- The cursor moves up by one physical line. The cursor will wrap from the top line of the display to the bottom line.

**CURSOR DOWN (\$1D)** -- The cursor moves down by one physical line. The cursor will wrap from the bottom line of the display to the top line.

**CURSOR LEFT (\$1E)** -- The cursor moves left by one column. The cursor will wrap from the left margin of a line to the right margin of the same line.

**CURSOR RIGHT (\$1F)** -- The cursor moves right by one column. The cursor will wrap from the right margin of a line to the left margin of the same line.

**BACKSPACE (\$7E)** -- The cursor moves left by one column (but never past the beginning of a logical line), and the character at that new position is changed to a blank (\$20).

SET TAB (\$9F) -- The Screen Editor establishes a tab point at the logical line position at that the cursor is residing. The logical line tab position is not synonymous with the physical line column position since the logical line can be up to 3 physical lines in length. For example, tabs can be set at the 15th, 30th, 45th, 60th and 75th character positions of a logical line as shown below:

|    |       |      |   |       |    |      |       |      |    |                  |
|----|-------|------|---|-------|----|------|-------|------|----|------------------|
| 0  | 2     |      | 9 |       | 19 |      | 29    |      | 39 | Screen column #. |
| -- | L     | ---- | + | ----  | +  | ---- | +     | ---- | R  | L/R = margins.   |
| xx | ----- |      | T | ----- |    | T    | ----- |      |    | A logical line.  |
| xx | ----- |      | T | ----- |    | T    | ----- |      | T  | x = inaccessible |
| xx | ----- |      |   | ----- |    |      | ----- |      |    | columns.         |

Note the effect of the left margin in defining the limits of the logical line.

The Handler default tab settings are shown below:

|    |      |      |      |      |      |      |      |      |      |                  |
|----|------|------|------|------|------|------|------|------|------|------------------|
| 0  | 2    |      | 9    |      | 19   |      | 29   |      | 39   | Screen column #. |
| -- | L    | ---- | +    | ---- | +    | ---- | +    | ---- | R    | L/R = margins.   |
| xx | T    | ---- | T    | ---- | T    | ---- | T    | ---- | T    | A logical line.  |
| xx | ---- | T    | ---- | T    | ---- | T    | ---- | T    | ---- | x = inaccessible |
| xx | ---- | T    | ---- | T    | ---- | T    | ---- | T    | ---- | columns.         |

CLEAR TAB (\$9E) -- The Screen Editor clears the current cursor position within the logical line from being a tab point. There is no "clear all tab points" facility provided by the Handler.

TAB (\$7F) -- The cursor moves to the next tab point in the current logical line, or to the beginning of the next line if no tab point is found. This function will not increase the logical line length to accommodate a tab point outside the current length (e.g. the logical line length is 38 characters and there is a tab point at position 50).

INSERT LINE (\$9D) -- All physical lines at and below the physical line in that the cursor resides, are moved down by one physical line. The last logical line on the display can be truncated as a result. The blank physical line at the insert point becomes the beginning of a new logical line. A logical line can be split into two logical lines by this process, the last half of the original logical line being concatenated with the blank physical line formed at the insert point.

DELETE LINE (\$9C) -- The logical line in that the cursor resides is deleted and all data below that line is moved upward to fill the void. Empty logical lines are created at the bottom of the display.

INSERT CHARACTER (\$FF) -- All physical characters at and behind the cursor position on a logical line are moved one position to the right. The character at the cursor position is set to blank. The last character of the logical line will be lost when the logical line is full and a character is inserted. The number of physical lines comprising a logical line can increase as a result of this function.

DELETE CHARACTER (\$FE) -- The character on which the cursor resides is removed, and the remainder of the logical line to the right of the deleted character is moved to the left by one position. The number of physical lines composing a logical line can decrease as a result of this function.

ESCAPE (\$1B) -- The next non-EOL character following this code is displayed as data, even if it would normally be treated as a control code. The sequence [ESC][ESC] will cause the second [ESC] character to be displayed.

BELL (\$FD) -- An audible tone is generated; the display is not modified.

END OF LINE (\$9B) -- In addition to its record termination function, the EOL causes the cursor to advance to the beginning of the next logical line. When the cursor reaches the bottom line of the screen, the receipt of an EOL will cause the screen data to scroll upward by one logical line.

#### GET STATUS

The Handler takes no action other than to set the status to \$01.

#### User-Alterable Data Base Variables

Also see the Display Handler data base variable discussion.

### Cursor Position

When in a split-screen configuration, ROWCRS and COLCRS are associated with the graphics portion of the display and two other variables, TXTROW [0290] and TXTCOL [0291], are associated with the text window. TXTROW is a single byte, and TXTCOL is 2-bytes with the least significant byte being at the lower address. Note that the most significant byte of TXTCOL should always be zero.

The home position (0,0) for the text window is the upper left corner of the window.

### Enable/Inhibit of Control Codes in Text

Normally all text mode control codes are operated upon as received, but sometimes it is desirable to have the control codes displayed as if they were data characters. This is done by setting the variable DSPFLG [02FE] to any nonzero value before outputting the data containing control codes. Setting DSPFLG to zero restores normal processing of text control codes.

## Cassette Handler (C:)

The Cassette device is a read or write device with a Handler that supports the following CIO functions:

- OPEN
- CLOSE
- GET CHARACTERS
- GET RECORD
- PUT CHARACTERS
- PUT RECORD
- GET STATUS (null function)

The Cassette Handler can produce the following error statuses:

- \$80 -- [BREAK] key abort.
- \$84 -- Invalid AUX1 byte on OPEN.
- \$88 -- end-of-file.
- \$8A-90 -- SIO error set (see Appendix C).

The Cassette Handler is one of the resident handlers, and therefore has a set of device vectors starting at location E440.

## CIO Function Descriptions

The device-specific characteristics of the standard CIO functions are detailed below:

### OPEN

The device name is C, and the Handler ignores any device number and filename specification, if included.

The Handler supports the following option:

```

 7 0
 +--+--+--+--+--+--+--+--+
AUX2 |C| |
 +--+--+--+--+--+--+--+--+

```

Where: C = 1 indicates that the cassette is to be read/written without stop/start between records (continuous mode).

Opening the cassette for input generates a single audible tone, as a prompt for you to verify that the cassette player is set up for reading (power on; Serial Bus cable connected; tape cued to start of file; and PLAY button depressed). When the cassette is ready, you can press any keyboard key (except [BREAK]) to initiate tape reading.

Opening the cassette for output generates two closely spaced audible tones, as a prompt for you to verify that the cassette player is set up for writing (as above, plus RECORD button depressed). When the cassette is ready, you can press any keyboard key (except [BREAK]) to begin tape writing. There is no way for the computer to verify that the RECORD or PLAY button is depressed. It is possible for the file not to be written, with no immediate indication of this fact.

There is a potential problem with the cassette in that when the cassette is opened for writing, the motor keeps running until the first record (128 data bytes) is written. If 128 data bytes are written or the cassette is closed within about 30 seconds of the OPEN, and no other serial bus I/O is performed, then there is no problem. However, if those conditions are not met, some noise will be written to the tape prior to the first record and an error will occur when that tape file is read later. If lengthy delays are anticipated between the time the cassette file is opened and the time that the first cassette record (128 data bytes) is written, then a dummy record should be written as part of the file; typically 128 bytes of some innocuous data would be written, such as all zeros, all \$FFs, or all blanks (\$20).

The system sometimes emits whistling noises after cassette I/O has occurred. The sound can be eliminated by storing \$03 to SKCTL [D20F], thus bring POKEY out of the two-tone (FSK) mode.

## CLOSE

The CLOSE of a tape read stops the cassette motor.

The CLOSE of a tape write does the following:

- Writes any remaining user data in the buffer to tape.
- Writes an end-of-file record.
- Stops the cassette motor.

## GET CHARACTERS and GET RECORD

The Handler returns data in the following format:

```
 7 0
+---+---+---+---+---+
! data byte !
+---+---+---+---+---+
```

## PUT CHARACTERS and PUT RECORD

The Handler accepts data in the following format:

```
 7 0
+---+---+---+---+---+
! data byte !
+---+---+---+---+---+
```

The Handler attaches no significance to the data bytes written, a value of \$9B (EOL) causes no special action.

## GET STATUS

The Handler does no more than set the status to \$01.

## Theory of Operation

The Cassette Handler writes and reads all data in fixed-length records of the format shown below:

```
+---+---+---+---+---+
!0 1 0 1 0 1 0 1! Speed measurement bytes.
+---+---+---+---+---+
!0 1 0 1 0 1 0 1!
+---+---+---+---+---+
! control byte !
+---+---+---+---+---+
! 128 !
= data =
! bytes !
+---+---+---+---+---+
! checksum ! (Managed by SIO, not the
+---+---+---+---+---+ Handler.)
```

Figure 5-9 Cassette Handler Record Format

The control byte contains one of three values:

- o \$FC indicates the record is a full data record (128 bytes).
- o \$FA indicates the record is a partially full data record; you supplied fewer than 128 bytes to the record. This case can occur only in the record prior to the end-of-file. The number of user-supplied data bytes in the record is contained in the byte prior to the checksum.
- o \$FE indicates the record is an End-of file record; the data portion is all zeroes for an end-of-file record.

The SIO routine generates and checks the checksum. It is part of the tape record, but it is not contained in the Handler's record buffer CASBUF [03FD].

The processing of the speed-measurement bytes during cassette reading is discussed in Appendix L, D1-D7.

### File Structure

The Cassette Handler writes a file to the cassette device with a file structure that is totally imposed by the Handler (soft format). A file consists of the following three elements:

- o A 20-second leader of mark tone.
- o Any number of data-record frames.
- o An end-of-file frame.

The cassette-data record frames are formatted as shown below:

```
frame = pre-record write tone (PRWT),
 + data record,
 + post record gap (PRG)
```

The nondata portions of a frame have characteristics that are dependent upon the write OPEN mode, i.e. continuous or start/stop.

```
Stop/start PRWT = 3 seconds of mark tone.
Continuous PRWT = .25 second of mark tone.
```

```
Stop/start PRG = up to 1 second of unknown tones.
Continuous PRG = from 0 to n seconds of unknown tones, where
 n is dependent upon your program timing.
```

The inter-record gap (IRG) between any two records consists of the PRG of the first record followed by the PRWT of the second record.

## Printer Handler (P:)

The Printer device is a write-only device with a Handler that supports the following CIO functions:

OPEN  
CLOSE  
PUT CHARACTERS  
PUT RECORD  
GET STATUS

The Printer Handler can produce the following error statuses:

\$8A-90 -- SIO error set (see Appendix C).

The Printer Handler is one of the resident handlers, and therefore has a set of device vectors starting at location E430.

### CIO Function Descriptions

The device-specific characteristics of the standard CIO functions are detailed below:

#### OPEN

The device name is P. The Handler ignores any device number and filename specification, if included.

#### CLOSE

The Handler writes any data remaining in its buffer to the printer device, with trailing blanks to fill out the line.

#### PUT CHARACTERS and PUT RECORD

The Handler accepts print data in the following format:

```
 7 0
+---+---+---+---+---+
! ATASCII !
+---+---+---+---+---+
```

The only ATASCII control code of any significance to the Handler is the EOL character. The printer device ignores bit 7 of every data byte and prints a sub set of the remaining 128 codes. (see Appendix G for the printer character set).

The Handler supports the following print option:

```

 7 0
 +---+---+---+---+---+
AUX2 | print mode |
 +---+---+---+---+---+

```

Where: \$4E (N) selects normal printing (40 characters per line).  
 \$53 (S) selects sideways printing (29 characters per line).  
 \$57 (W) selects wide printing (not supported by printer device).

Any other value (including 00) is treated as a normal (N) print select, without producing an error status.

## GET STATUS

The Handler obtains a 4-byte status from the printer controller and puts it in system location DVSTAT [02EA]. The format of the status bytes is shown below:

```

 +---+---+---+---+---+
 | command stat. | DVSTAT + 0
 +---+---+---+---+---+
 | AUX2 of prev. | + 1
 +---+---+---+---+---+
 | timeout | + 2
 +---+---+---+---+---+
 | (unused) | + 3
 +---+---+---+---+---+

```

The command status contains the following status bits and condition indications:

bit 0: an invalid command frame was received.  
 bit 1: an invalid data frame was received.  
 bit 7: an intelligent controller (normally = 0).

The next byte contains the AUX2 value from the previous operation.

The timeout byte contains a controller provided maximum timeout value (in seconds).

## Theory of Operation

The ATARI 820[TM] 40-Column Printer is a line-at-a-time printer rather than a character-at-a-time printer, so your data must be buffered by the Handler and sent to the device in records corresponding to one print line (40 characters for normal, 29 characters for sideways).

The printer device does not attach any significance to the EOL character, so the Handler does the appropriate blank fill whenever it sees an EOL.

#### Disk File Manager (D:)

The OS supports four unique File Management Subsystems at the time of this writing. Version IA is the original version. Version IB is a slightly modified version of IA and is the one described in this document. Most of this discussion applies as well to Version II, that handles a double-density diskette (720 256-byte sectors) in addition to the single-density diskette (720 128-byte sectors). Version III has all new file/directory/map structures and can possibly contain changes to your interface as well.

The File Management Subsystem includes a disk-bootable (RAM-resident) Disk File Manager (DFM) that maintains a collection of named files on diskettes. Up to 4 disk drives (D1: through D4:) can be accessed, and up to 64 files per diskette can be accessed. The system diskettes supplied by ATARI allow a single disk drive (D1) and up to 3 OPEN files, but you can alter these numbers as described later in this section.

The Disk File Manager supports the following CIO functions:

- OPEN FILE
- OPEN DIRECTORY
- CLOSE
- GET CHARACTERS
- GET RECORD
- PUT CHARACTERS
- PUT RECORD
- GET STATUS

- NOTE
- POINT
- LOCK
- UNLOCK
- DELETE
- RENAME
- FORMAT

The Disk File Manager can produce the following error statuses:

\$03 -- Last data from file (EOF on next read).  
\$88 -- end-of-file.  
\$8A-90 -- SIO error set (see Appendix C).  
\$A0 -- Drive number specification error.  
\$A1 -- No sector buffer available (too many open files).  
\$A2 -- Disk full.  
\$A3 -- Fatal I/O error in directory or bitmap.  
\$A4 -- Internal file # mismatch (structural problem).  
\$A5 -- File name specification error.  
\$A6 -- Point information in error.  
\$A7 -- File locked to this operation.  
\$A8 -- Special command invalid.  
\$A9 -- Directory full (64 files).  
\$AA -- File not found.  
\$AB -- Point invalid (file not OPENed for update).

#### CIO Function Descriptions

The device-specific characteristics of the standard CIO functions are detailed below:

##### OPEN FILE

The device name is D. Up to four disk drives can be accessed (D1 through D4). The disk filename can be from 1 to 8 characters in length with an optional 1- to 3-character extension.

The OPEN FILE command supports the following options:

|      | 7 |       | 0   |
|------|---|-------|-----|
|      | + | +     | +   |
| AUX1 | ! | !W!R! | !A! |
|      | + | +     | +   |

Where: W and R are the direction bits.

WR = 00 is invalid

01 indicates OPEN for read only.

10 indicates OPEN for write only.

11 indicates OPEN for read/write (update).

A = 1 indicates appended output when W = 1.

You may use these following valid AUX1 options:

#### OPEN Input (AUX1 = \$04)

The indicated file is opened for input. Any wild-card characters are used to search for the first match. If the file is not found, an error status is returned, and no file will be opened.

#### OPEN Output (AUX1 = \$08)

The indicated file is opened for output starting with the first byte of the file, if the file is not locked. Any wild-card characters are used to search for the first match. If the file already exists, the existing file will be deleted before opening the named file as a new file. If the file does not already exist, it will be created.

A file opened for output will not appear in the directory until it has been closed. If an output file is not properly closed, some or all of the sectors that were acquired for it can be lost until the disk is reformatted.

A file that is opened for output can not be opened concurrently for any other access.

#### OPEN Append (AUX1 = \$09)

The indicated file is opened for output starting with the byte after the last byte of the existing file (that must already exist), if the file is not locked. Any wild-card characters are used to search for the first match.

If a file opened for append is not properly closed, the appended data will be lost. The existing file will remain unmodified and some or all of the sectors that were acquired for the appended portion can be lost until the diskette is reformatted.

#### OPEN Update (AUX1 = \$0C)

The indicated file (that must already exist) will be opened for update provided it is not locked. Any wild-card characters are used to search for the first match.

The GET, PUT, NOTE and POINT operations are all valid, and can be intermixed as desired.

If a file opened for update is not properly closed, a sector's worth of information can be lost to the file. A file opened for update can not be extended.

## Device/Filename Specification

The Handler expects to find a device/filename specification of the following form:

D[<number>]:<filename><EOL>

where:

<number> ::= 1|2|3|4

<filename> ::= [<primary>][.<extension>]<terminator>

<primary> ::= an uppercase alpha character followed by 0 to 7 alphanumeric characters. If the primary name is less than 8 characters, it will be padded with blanks; if it is greater than 8 characters, the extra characters will be ignored.

<extension> ::= Zero to 3 alphanumeric characters. If the extension name is missing or less than 3 characters, it will be padded with blanks; if it is greater than 3 characters, the extra characters will be ignored.

<terminator> ::= <EOL>|<blank>

Figure 5-10 Device/Filename Syntax

The following are all valid device/filenames for the diskette:

D1:GAME.SRC  
D:MANUAL6  
D:.WHY  
D3:FILE.  
D4:BRIDGE.002

## Filename Wildcarding

The filename specification can be further generalized to include the use of the "wild-card" characters \* and ?. These wildcard characters allow portions of the primary and/or extension to be abbreviated as follows:

The ? character in the specification allows any filename character at that position to produce a "match." For example, WH? will match files named WHO, WHY, WH4, etc., but not a file named WHAT.

The \* character causes the remainder of the primary or extension field in that it is used to be effectively padded with ? characters. For example, WH\* will match WHO, WHEN, WHATEVER, etc.

Some valid uses of wild-card specifications are shown below:

|         |                                                                 |
|---------|-----------------------------------------------------------------|
| *.SRC   | Files having an extension of SRC.                               |
| BASIC.* | Files named BASIC with any extension.                           |
| *.*     | All files.                                                      |
| H*.*    | Files beginning with H and having a 0 or 1 character extension. |

If wildcarding is used with an OPEN FILE command, the first file found (if any) that meets the specification will be the one (and only one) opened.

## OPEN DIRECTORY

The OPEN DIRECTORY command allows you read directory information for the selected filename(s), using normal GET CHARACTERS or GET RECORD commands. The information read will be formatted as ATASCII records, suitable for printing, as shown below. Wildcarding can be used to obtain information for multiple files or the entire diskette.

The OPEN DIRECTORY command uses the same CIO parameters as a standard OPEN FILE command:

COMMAND BYTE = \$03

BUFFER ADDRESS = pointer to device/filename specification.

AUX1 = \$06

After the directory is opened, a record will be returned to the caller for each file that matches the OPEN specification. The record, that contains only ATASCII characters, is formatted as shown below:

```

 1
1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8
+---+---+---+---+---+---+---+---+
|s|b| primary name | ext |b|count|e|
+---+---+---+---+---+---+---+---+

```

Where: s = \* or ' ', with \* indicating file locked.  
 b = blank.  
 primary name = left-justified name with blank fill.  
 ext = left-justified extension with blank fill.  
 b = blank.  
 count = number of sectors comprising the file.  
 e = EOL (\$9B).

After the last filename match record is returned, an additional record is returned. This record indicates the number of unused sectors available on the diskette. The format for this record is shown below:

```

 1
1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7
+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+
!count! F R E E S E C T O R S!e!
+--+--+--+--+--+--+--+--+--+--+--+--+--+--+--+

```

Where: count = the number of unused sectors on the diskette.  
 e = EOL (\$9B).

The EOF statuses (\$03 and \$88) are returned as in a normal data file when the last directory record is read.

The opening of another diskette file while the directory read is open will cause subsequent directory reads to malfunction, so care must be taken to avoid this situation.

## CLOSE

Upon closing a file read, the Handler releases all internal resources being used to support that file.

Upon closing a file write, the Handler:

- o writes any residual data from its file buffer for that file to the diskette.
- o updates the directory and allocation map for the associated diskette.
- o releases all internal resources being utilized to support that file

## GET CHARACTERS and GET RECORD

Characters are read from the diskette and passed to CIO as a raw data stream. None of the ATASCII control characters have any special significance. A status of \$88 is returned if an attempt is made to read past the last byte of a file.

## PUT CHARACTERS and PUT RECORD

Characters are obtained from CIO and written to the diskette as a raw data stream. None of the ATASCII control characters have any special significance.

## GET STATUS

The indicated file is checked and one of the following status byte values is returned in ICSTA and register Y:

- \$01 -- File found and unlocked.
- \$A7 -- File locked.
- \$AA -- File not found.

## Special CIO Functions

The DFM supports a number of SPECIAL commands, that are device specific. These are explained in the paragraphs that follow:

### NOTE (COMMAND BYTE = \$25)

This command returns to the caller the exact diskette location of the next byte to be read or written, in the variables shown below:

- ICAX3 = LSB of the diskette sector number.
- ICAX4 = MSB of the diskette sector number.
- ICAX5 = relative sector displacement to byte (0-124).

### POINT (COMMAND BYTE = \$26)

This command allows you to specify the exact diskette location of the next byte to be read or written. In order to use this command, the file must have been opened with the "update" option.

- ICAX3 = LSB of the diskette sector number.
- ICAX4 = MSB of the diskette sector number.
- ICAX5 = relative sector displacement to byte (0-124).

## LOCK

This command allows you to prevent write access to any number of named files. Locked files can not be deleted, renamed, nor opened for output unless they are first unlocked. Locking a file that is already locked is a valid operation. The Handler expects a device/filename specification; then all occurrences of the filename specified will be locked, using the wild-card rules.

You set up these following IOCB parameters prior to calling CIO:

COMMAND BYTE = \$23

BUFFER ADDRESS = pointer to device/filename specification.

After a LOCK operation, the following IOCB parameter will have been altered:

STATUS = result of LOCK operation; see Appendix B for a list of possible status codes.

## UNLOCK

This command allows you to remove the lock status of any number of named files. Unlocking a file that is not locked is a valid operation. The Handler expects a device/filename specification; then all occurrences of the filename specified will be unlocked, using the wild-card rules.

You set up these following IOCB parameters prior to calling CIO:

COMMAND BYTE = \$24

BUFFER ADDRESS = pointer to device/filename specification.

After an UNLOCK operation, the following IOCB parameter will have been altered:

STATUS = result of UNLOCK operation; see Appendix B for a list of possible status codes.

## DELETE

This command allows you to delete any number of unlocked named files from the directory of the selected diskette and to deallocate the diskette space used by the files involved. The Handler expects a device/filename specification; then all occurrences of the filename specified will be deleted, using the wild-card rules.

You set up these following IOCB parameters prior to calling CIO:

COMMAND BYTE = \$21

BUFFER ADDRESS = pointer to device/filename specification.

After a DELETE operation, the following IOCB parameter will have been altered:

STATUS = result of DELETE operation; see Appendix B for a list of possible status codes.

## RENAME

This command allows you to change the filenames of any number of unlocked files on a single diskette. The Handler expects to find a device/filename specification that follows:

<device spec>:<filename spec>,<filename spec><EOL>

All occurrences of the first filename will be replaced with the second filename, using the wild-card rules. No protection is provided against forming duplicate names. Once formed, duplicate names cannot be separately renamed or deleted; however, an OPEN FILE command will always select the first file found that matches the filename specification, so that file will always be accessible. The RENAME command does not alter the content of the files involved, merely the name in the directory.

Examples of some valid RENAME name specifications are shown below:

D1:\*.SRC,\*.TXT  
D:TEMP,FDATA  
D2:F\*,F\*.OLD

You set up these following IOCB parameters prior to calling CIO:

COMMAND BYTE = \$20

BUFFER ADDRESS = pointer to device/filename specification.

After a RENAME operation, the following IOCB parameter will have been altered:

STATUS = result of RENAME operation; see Appendix B for a list of possible status codes.

## FORMAT

Soft-sector diskettes must be formatted before they can store data. The FORMAT command allows you to physically format a diskette. The physical formatting process writes a new copy of every sector on the soft-sectored diskette, with the data portion of each sector containing all zeros. The FORMAT process creates an "empty" non system diskette. When the formatting process is complete, the FMS creates an initial Volume Table of Contents (VTOC) and an initial File Directory. The boot sector (#1) is permanently reserved as part of this process.

You set up these following IOCB parameters prior to calling CIO:

COMMAND BYTE = \$FE

BUFFER ADDRESS = pointer to device specification.

After a FORMAT operation, the following IOCB parameter will have been altered:

STATUS = result of FORMAT operation; see Appendix B for a list of possible status codes.

To create a system diskette, a copy of the boot file must then be written to sectors #2-n. This is accomplished by writing the file named DOS.SYS. This is a name that is recognized by the FMS even though it is not in the directory initially.

## Theory of Operation

The resident OS initiates the disk-boot process (see Section 10). The OS reads diskette sector #1 to memory and then transfers control to the "boot continuation address" (boot address + 6). The boot-continuation program contained in sector #1 then continues to load the remainder of the File Management Subsystem to memory using additional information contained in sector #1. The File Management Subsystem loaded, will contain a Disk File Manager, and optionally, a Disk Utilities (DOS) package.

When the boot process is complete, the Disk File Manager will allocate additional RAM for the creation of sector buffers. Sector buffers are allocated based upon information in the boot record as shown below:

Byte 9 = maximum number of open files; one buffer per (the maximum value is 8).

Byte 10 = drive select bits; one buffer per (1-4 only).

The Disk File Manager will then insert the name D and the Handler vector table address in the device table.

NOTE: There is a discrepancy between the Disk File Manager's numbering of diskette sectors (0-719) and the disk controller's numbering of diskette sectors (1-720); as a result, only sectors 1- 719 are used by the Disk File Manager.

The Disk File Manager uses the Disk Handler to perform all diskette reads and writes; the DFM's function is to support and maintain the directory/file/bitmap structures as described in the following pages:

## FMS Diskette Utilization

The map below shows the diskette sector utilization for a standard 720 sector diskette.

|               |                    |
|---------------|--------------------|
| +-----+       |                    |
| BOOT record   | Sector 1           |
| +-----+       |                    |
| FMS BOOT      | Sector 2 --+       |
| = file =      |                    |
| DOS.SYS       | Sector n +- Note 1 |
| +-----+       |                    |
| User          | Sector n+1 --+     |
| = File =      |                    |
| Area          | Sector 359 (\$167) |
| +-----+       |                    |
| VTOC(note 2)  | Sector 360 (\$168) |
| +-----+       |                    |
| File          | Sector 361 (\$169) |
| = Directory = |                    |
|               | Sector 368 (\$170) |
| +-----+       |                    |
| User          |                    |
| = File =      |                    |
| Area          | Sector 719 (\$2CF) |
| +-----+       |                    |
| unused        | Sector 720 (\$2D0) |
| +-----+       |                    |

Figure 5-11 File Management Subsystem Diskette Sector Utilization Map

NOTE 1 - If the diskette is not a system diskette, then your File Area starts at sector 2 and no space is reserved for the FMS BOOT file. However, "DOS" (DOS.SYS and DUP.SYS) may still be written to a diskette that has already used sectors "2-N."

NOTE 2 -- VTOC stands for Volume Table of Contents.

## FMS Boot Record Format

The FMS BOOT record (sector #1) is a special case of diskette-booted software (see Section 10). The format for the FMS BOOT record is shown below:

|                  |        |                        |
|------------------|--------|------------------------|
| +-----+          |        |                        |
| boot flag = 0    | Byte 0 |                        |
| +-----+          |        |                        |
| # sectors = 1    | 1      |                        |
| +-----+          |        |                        |
| boot address     | 2      |                        |
| +-----+          |        |                        |
| = 0700           |        |                        |
| +-----+          |        |                        |
| init address     | 4      |                        |
| +-----+          |        |                        |
| JMP = \$4B       | 6      |                        |
| +-----+          |        |                        |
| boot read        |        |                        |
| + continuation + |        |                        |
| address          |        |                        |
| +-----+          |        |                        |
| max files = 3    | 9      | Note 1                 |
| +-----+          |        |                        |
| drive bits = 1   | 10     | Note 2                 |
| +-----+          |        |                        |
| alloc dirc = 0   | 11     | Note 3                 |
| +-----+          |        |                        |
| boot image end   |        |                        |
| +-----+          |        |                        |
| address + 1      |        | FMS configuration data |
| +-----+          |        |                        |
| boot flag <> 0   | 14     | Note 4                 |
| +-----+          |        |                        |
| sector count     | 15     | Note 5                 |
| +-----+          |        |                        |
| DOS.SYS          |        |                        |
| + starting +     |        |                        |
| sector number    |        |                        |
| +-----+          |        |                        |
| code for second  |        |                        |
| phase of boot    |        |                        |

Figure 5-12 File Management Subsystem Boot Record Format

NOTE 1 - Byte 9 specifies the maximum number of concurrently open files to be supported. This value can range from 1 to 8.

NOTE 2 - Byte 10 specifies the specific disk drive numbers to be supported using a bit encoding scheme as shown below:

```
 7 6 5 4 3 2 1 0
+---+---+---+---+
| |4|3|2|1| where a 1 indicates a selected drive.
+---+---+---+---+
```

NOTE 3 - Byte 11 specifies the buffer allocation direction, this byte should equal 0.

NOTE 4 - Byte 14 must be nonzero for the second phase of the boot process to initiate. This flag indicates that the file DOS.SYS has been written to the diskette.

NOTE 5 - This byte is assigned as being the sector count for the DOS.SYS file. It is actually an unused byte.

## Boot Process Memory Map

The diagram below shows how the boot sector (part of file DOS.SYS) and following sectors are loaded to memory as part of the boot process.

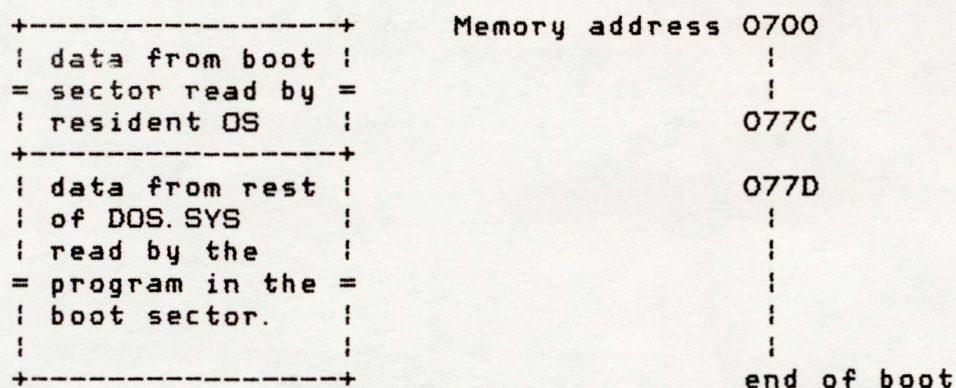


Figure 5-13 File Management Subsystem Boot Process Memory Map

## Volume Table of Contents

The format for the FMS volume table of contents (VTOC, sector 360) is shown in the diagram below:

|                    |               |
|--------------------|---------------|
| +-----+            |               |
| directory type     | Byte 0 Note 1 |
| +-----+            |               |
| maximum (lo)       | 1 Note 2      |
| + sector # +       |               |
| = 0205 (hi)        |               |
| +-----+            |               |
| number of (lo)     | 3 Note 3      |
| + sectors +        |               |
| available (hi)     |               |
| +-----+            |               |
|                    |               |
| =                  |               |
|                    |               |
| +-----+            |               |
|                    | 10            |
| = volume bit map = |               |
|                    |               |
| +-----+            |               |
|                    |               |
| =                  |               |
|                    |               |
| +-----+            |               |

Figure 5-14 File Management Subsystem Volume Table of Contents

The volume bit map organization location follows:

|                  |                 |  |
|------------------|-----------------|--|
| 7                | 0               |  |
| +--+--+--+--+--+ |                 |  |
| 1 2 3 4 5 6 7    | Byte 10 of VTOC |  |
| +--+--+--+--+--+ |                 |  |
| 8 9 . . . . .    | 11              |  |
| =                |                 |  |
|                  | 99              |  |
| +--+--+--+--+--+ |                 |  |

Figure 5-15 File Management Subsystem Volume Bit Map

At each map bit position, a 0 indicates the corresponding sector is in use and a 1 indicates that the sector is available.

NOTE 1 - The directory type byte must equal 0.

NOTE 2 - The maximum sector number is not used because it is incorrectly set to 709 decimal. The true maximum sector number is actually 719 for the DFM.

NOTE 3 - The number of sectors available is initially set to 709 after a diskette is freshly formatted; this number is adjusted as files are created and deleted to show the number of sectors available. The sectors that are initially reserved are 1 and 360-368.

### File Directory Format

The FMS reserves eight sectors (361-368) for a file directory. Each sector containing directory information for up to eight files, thus providing for a maximum of 64 files for any volume. The format of a single 16-byte file entry is shown below:

|               |        |
|---------------|--------|
| +-----+       |        |
| flag byte     | Byte 0 |
| +-----+       |        |
| sector (lo)   | 1      |
| + count +     |        |
| (hi)          |        |
| +-----+       |        |
| starting (lo) | 3      |
| + sector +    |        |
| number (hi)   |        |
| +-----+       |        |
| (1)           | 5      |
| + +           |        |
| (2)           |        |
| + +           |        |
| (3)           |        |
| + +           |        |
| file (4)      |        |
| + +           |        |
| name (5)      |        |
| + +           |        |
| primary (6)   |        |
| + +           |        |
| (7)           |        |
| + +           |        |
| (8)           |        |
| +-----+       |        |
| file (1)      | 13     |
| + +           |        |
| name (2)      |        |
| + +           |        |
| extension (3) |        |
| +-----+       |        |

Figure 5-16 File Directory Format

Where the flag byte has the following bits assigned:

bit 7 = 1 if the file has been deleted.  
 bit 6 = 1 if the file is in use.  
 bit 5 = 1 if the file is locked.  
 bit 0 = 1 if OPEN output.

The flag byte can take on the following values:

\$00 = entry not yet used (no file).  
 \$40 = entry in use (normal CLOSEd file).  
 \$41 = entry in use (OPEN output file).  
 \$60 = entry in use (locked file).  
 \$80 = entry available (prior file deleted).

Sector count is the number of sectors comprising the file.

#### FMS File Sector Format

The format of a sector in your data file is shown below:

```

 7 0
+---+---+---+---+---+
| data | +0
+---+---+---+---+---+
| | |
+---+---+---+---+---+
| file # |hi | | +125
+---+---+---+---+---+
|forward pointer| | +126
+---+---+---+---+---+
|S| byte count | | +127
+---+---+---+---+---+

```

Figure 5-17 File Management Subsystem File Sector Format

The FMS uses the file # to verify file integrity. The file # is a redundant piece of information. The file number field contains the value of the directory position of that file. If a mismatch occurs between the file's directory position, and the file number as contained in each sector, then the DFM will generate the error \$A4.

The forward pointer field contains the 10-bit value for the diskette sector number of the next sector of the file. The pointer equals zero for the last sector of a file.

The S bit indicates whether or not the sector is a "short sector" (a sector containing fewer than 125 data bytes). S is equal to 1 when the sector is short.

The byte-count field contains the number of data bytes in the sector.

## Non-CIO I/O

Some portions of the I/O subsystem are accessed independently of the Central I/O Utility (CIO); this section discusses those areas.

## Resident Device Handler Vectors

All of the OS ROM resident device handlers can be accessed via sets of vectors that are part of the OS ROM. These vectors increase the speed of I/O operations that utilize fixed device assignments, such as output to the Display Handler. For each resident Handler there is a set of vectors ordered as shown below:

|                    |     |
|--------------------|-----|
| +-----+            |     |
| +-- OPEN --+       | +0  |
| +-----+            |     |
| +-- CLOSE --+      | +2  |
| +-----+            |     |
| +-- GET BYTE --+   | +4  |
| +-----+            |     |
| +-- PUT BYTE --+   | +6  |
| +-----+            |     |
| +-- GET STATUS --+ | +8  |
| +-----+            |     |
| +-- SPECIAL --+    | +10 |
| +-----+            |     |
| +-- JMP --+        | +12 |
| +-- INIT --+       |     |
| +-----+            |     |
| +-- SPARE --+      |     |
| +-- BYTE --+       |     |
| +-----+            |     |

Figure 5-18 Resident Device Handler Vectors

See Section 9 for a detailed description of the data interface for each of these Handler entry points.

Each of the vectors contains the address (lo,hi) of the Handler entry point minus 1. A technique similar to the one shown below is required to access the desired routines:

```

VTBASE=$E400 ; BASE OF VECTOR TABLE.

 LDX #xx ; OFFSET TO DESIRED ROUTINE.
 LDA data
 JSR GOVEC ; SEND DATA TO ROUTINE.

 LDX #yy ; OFFSET TO DIFFERENT ROUTINE.
 JSR GOVEC ; GET DATA FROM ROUTINE.
 STA data

GOVEC TAY ; SAVE REGISTER A.
 LDA VTBASE+1,X ; ADDRESS MSB TO STACK.
 PHA
 LDA VTBASE,X ; ADDRESS LSB TO STACK.
 PHA
 TYA ; RESTORE REGISTER A.
 RTS ; JUMP TO ROUTINE.

```

The JMP INIT slot in each set of vectors jumps to the Handler initialization entry (not minus 1).

The base address of the vector set for each of the resident handlers is shown below:

|                       |       |
|-----------------------|-------|
| Screen Editor (E:)    | E400. |
| Display Handler (S:)  | E410. |
| Keyboard Handler (K:) | E420. |
| Printer Handler (P:)  | E430. |
| Cassette Handler (C:) | E440. |

The resident diskette Handler is not CIO-compatible, so its interface does not use a vector set.

#### Resident Diskette Handler

The resident Diskette Handler (not to be confused with the Disk File Manager) is responsible for all physical accesses to the diskette. The unit of data transfer for this Handler is a single diskette sector containing 128 data bytes.

Communication between you and the Diskette Handler is effected using the system's Device Control Block (DCB), that is also used for Handler/SIO communication (see Section 9). The DCB is 12 bytes long. Some bytes are user-alterable and some are for use by the Diskette Handler and/or the Serial I/O Utility (SIO). You supply the required DCB parameters and then do a JSR DSKINV [E453].

Each of the DCB bytes will now be described, and the system-equate file name for each will be given.

#### SERIAL BUS ID -- DDEVIC [0300]

The Diskette Handler sets up this byte to contain the Serial Bus ID for the drive to be accessed. It is not user-alterable.

#### DEVICE NUMBER -- DUNIT [0301]

You set up this byte to contain the disk drive number to be accessed (1 - 4).

#### COMMAND BYTE -- DCOMND [0302]

You set up this byte to contain the disk device command to be performed.

#### STATUS BYTE -- DSTATS [0303]

This byte contains the status of the command upon return to the caller. See Appendix C for a list of the possible status codes.

#### BUFFER ADDRESS -- DBUFLO [0304] and DBUFHI [0305]

This 2-byte pointer contains the address of the source or destination of the diskette sector data. You need not supply an address for the disk status command. The Disk Handler will obtain the status and insert the address of the status buffer into this field.

#### DISK TIMEOUT VALUE -- DTIMLO [0306]

The Handler supplies this timeout value (in whole seconds) for use by SIO.

#### BYTE COUNT -- DBYTLO [0308] and DBYTHI [0309]

This 2-byte counter indicates the number of bytes transferred to or from the disk as a result of the most recent command, and is set up by the Handler.

#### SECTOR NUMBER -- DAUX1 [030A] and DAUX2 [030B]

This 2-byte number specifies the diskette sector number (1 - 720) to read or write. DAUX1 contains the least significant byte, and

DAUX2 contains the most significant byte.

#### Diskette Handler Commands

There are five commands supported by the Diskette Handler:

GET SECTOR (PUT SECTOR ---\*\*\* not supported by current handler \*\*\*)  
PUT SECTOR WITH VERIFY  
STATUS REQUEST  
FORMAT DISK

#### GET SECTOR (Command byte = \$52)

The Handler reads the specified sector to your buffer and returns the operation status. You set the following DCB parameters prior to calling the Diskette Handler:

COMMAND BYTE = \$52.

DEVICE NUMBER = disk drive number (1-4).

BUFFER ADDRESS = pointer to your 128-byte buffer.

SECTOR NUMBER = sector number to read.

Upon return from the sector, several of the other DCB parameters will have been altered. The STATUS BYTE will be the only parameter of interest to you, however.

#### PUT SECTOR (Command byte = \$50)

\*\*\* Not supported by current Handler \*\*\*  
(But can be accessed through SIO directly.)

The Handler writes the specified sector from your buffer and returns the operation status. You set the following DCB parameters prior to calling the Diskette Handler:

COMMAND BYTE = \$50.

DEVICE NUMBER = disk drive number (1-4).

BUFFER ADDRESS = pointer to your 128 byte buffer.

SECTOR NUMBER = sector number to write.

Upon return from the operation, several of the other DCB parameters will have been altered. The STATUS BYTE will be the only one of interest you, however.

## PUT SECTOR WITH VERIFY (Command Byte = \$57)

The Handler writes the specified sector from your buffer and returns the operation status. This command differs from PUT SECTOR in that the diskette controller reads the sector data after writing to verify the write operation. Aside from the COMMAND BYTE value, the calling sequence is identical to PUT SECTOR.

## STATUS REQUEST (Command byte = \$53)

The Handler obtains a 4-byte status from the diskette controller and puts it in system location DVSTAT [02EA]. The operation status format is shown below:

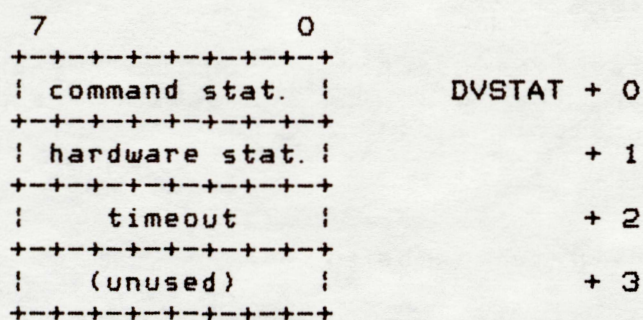


Figure 5-19. DVSTAT 40-Byte Operation Status Format

The command status contains the following status bits:

- Bit 0 = 1 indicates an invalid command frame was received.
- Bit 1 = 1 indicates an invalid data frame was received.
- Bit 2 = 1 indicates that a PUT operation was unsuccessful.
- Bit 3 = 1 indicates that the diskette is write protected.
- Bit 4 = 1 indicates active/standby.

The hardware status byte contains the status register of the INS1771-1 Floppy Diskette Controller chip used in the diskette controller. See the documentation for that chip to obtain information relating to the meaning of each bit in the byte.

The timeout byte contains a controller-provided maximum timeout value (in seconds) to be used by the Handler.

You set the following DCB parameters prior to calling the Diskette Handler:

COMMAND BYTE = \$53.

DEVICE NUMBER = disk drive number (1-4).

Upon return from the operation, several of the other DCB parameters will have been altered. The STATUS BYTE will be the only one of

interest to you, however.

#### FORMAT DISK (Command Byte = \$21)

The Handler commands the diskette controller to format the entire diskette and then to verify it. All bad sector numbers (up to a maximum of 63) are returned and put in the supplied buffer, followed by two bytes of all 1's (\$FFFF). You set up the following DCB parameters prior to calling the Diskette Handler:

COMMAND BYTE = \$21.

DEVICE NUMBER = disk drive number (1-4).

BUFFER ADDRESS = pointer to your 128-byte buffer.

Upon return, you might be interested in the following DCB parameters:

STATUS BYTE = status of operation.

BYTE COUNT = number of bytes of bad sector information in your buffer, not including the \$FFFF terminator. If there are no bad sectors, the count will equal zero.

#### Serial Bus I/O

Input/Output to devices other than the keyboard, the screen, and the ATARI Computer controller port devices, must utilize the Serial I/O bus. This bus contains data, control, and clock lines to be used to allow the computer to communicate with external devices on this "daisy chained" bus. Every device on the bus has a unique identifier and will respond only when directly addressed.

The resident system provides a Serial I/O Utility (SIO), that provides a standardized high-level program interface to the bus. SIO is utilized by the resident Diskette, Printer, and Cassette handlers, and is intended to be used by nonresident handlers (see Section 9), or by applications, as well. For a detailed description of the program/SIO interface and for a detailed bus specification refer to Section 9.

## 6 INTERRUPT PROCESSING

Section 6 describes system actions for the various interrupt causing events, defines the many RAM vectors and provides recommended procedures for dealing with interrupts.

The 6502 microcomputer processes three general interrupt types: chip-reset, nonmaskable interrupts (NMI) and maskable interrupts (IRQ). The IRQ interrupt type can be enabled and disabled using the 6502 CLI and SEI instructions. The NMI type cannot be disabled at the processor level; but the NMI interrupts other than [SYSTEM.RESET] key can be disabled at the ANTIC chip.

The system events that can cause interrupts are listed below:

- chip-reset - power-up

- NMI - Display list interrupt (unused by OS)  
vertical-blank (50/60 Hz)  
[SYSTEM.RESET] key

- IRQ - Serial bus output ready  
Serial bus output complete  
Serial bus input ready  
Serial bus proceed line (unused by system)  
Serial bus interrupt line (unused by system)  
POKEY timers 1, 2 and 4  
Keyboard key  
[BREAK] key  
6502 BRK instruction (unused by OS)

Figure 6-1 List of System-Interrupt Events

The chip-reset interrupt is vectored via location FFFC to E477, where a JMP vector to the power-up routine is located. All NMI interrupts are vectored via location FFFA to the NMI interrupt service routine at E7B4, and all IRQ interrupts are vectored via location FFFE to the IRQ interrupt service routine at E6F3; at that point the cause of the interrupt must be determined by a series of tests. For some of the events there are built in monitor actions and for other events the corresponding interrupts are disabled or ignored. The system provides RAM vectors so that you can intercept interrupts when necessary.

## CHIP-RESET

The OS generates chip-reset in response to a power-up condition. The system is completely initialized (see Section 7).

## NONMASKABLE INTERRUPTS

When an NMI interrupt occurs, control is transferred through the RDM vector directly to the system NMI interrupt service routine. A cause for the interrupt is determined by examining hardware register NMIST [D40F]. The NMI makes a jump through the global RAM vector VDSLST [0200] if a display list interrupt is pending. The OS does not use display list interrupts, so VDSLST is initialized to point to an RTI instruction, and you must not change it before VDSLST generates a display interrupt.

If the interrupt is not a display-list interrupt, then a test is made to see if it is a [SYSTEM.RESET] key interrupt. If so, then a jump is made to the system reset initialization routine (see Section 7 for details of system reset initialization).

If the interrupt is neither a display list interrupt nor a [SYSTEM.RESET] key interrupt; then it is assumed to be a vertical-blank (VBLANK) interrupt, and the following actions occur:

Registers A, X and Y are pushed to the stack.

The interrupt request is cleared (NMIRES [D40F]).

A jump is made through the "immediate" vertical-blank global RAM vector VVBLKI [0222] that normally points to the Stage 1 VBLANK processor.

The following actions occur assuming that you have not changed VVBLKI.

The stage 1 VBLANK processor is executed.

The OS tests to see if a critical code section has been interrupted. If so; then all registers are restored, and an RTI instruction returns from the interrupt to the critical section. A critical section is determined by examining the CRITIC flag [0042], and the processor I bit. If either are set, then the interrupted section is assumed to be critical.

If the interrupt was not from a critical section, then the stage 2 VBLANK processor is executed.

The OS then jumps through the "deferred" vertical-blank global RAM vector VBLKD [0224], that normally points to the VBLANK exit routine.

The following actions occur assuming that you have not changed VVBLKD.

- o The 6502 A,X and Y registers are restored.
- o An RTI instruction is executed.

NOTE: You can alter the deferred and immediate VBLANK RAM vectors, but still enable normal system processes; or restore original vectors without having to save them. The instruction at E45F is a JMP to the stage 1 VBLANK processor; the address at [E460,2] is the value normally found in VVBLKI. The instruction at E462 is a JMP to the VBLANK exit routine; the address at [E463,2] is the value normally found in VVBLKD. These ROM vectors to stage 1 VBLANK processor and to the VBLANK exit routine will accomplish your goal.

NOTE: Every VBLANK interrupt jumps through vector VVBLKI. Only VBLANK interrupts from noncritical code sections jump through vector VVBLKD.

### Stage 1 VBLANK Process

The following stage 1 VBLANK processing is performed at every VBLANK interrupt:

The stage 1 VBLANK process increments the 3-byte frame counter RTCLOK [0012-0014]; RTCLOK+0 is the MSB and RTCLOK+2 is the LSB. This counter wraps to zero when it overflows (every 77 hours or so), and continues counting.

The Attract mode variables are processed (see Appendix L, B10-12).

The stage 1 VBLANK process decrements the System Timer 1 CDTMV1 [0218,2] if it is nonzero; if the timer goes from

nonzero to zero then an indirect JSR is performed via CDTMA1 [0226,2].

## Stage 2 VBLANK Process

The stage 2 VBLANK processing performs the following for those VBLANK interrupts that do not interrupt critical sections:

The stage 2 VBLANK process clears the 6502 processor I bit. This enables the IRQ interrupts.

The stage 2 VBLANK process updates various hardware registers with data from the OS data base, as shown below:

| Data Base Item | Hardware Register | Reason for Update    |
|----------------|-------------------|----------------------|
| SDLSTH [0231]  | DLISTH [D403]     | Display list start   |
| SDLSTL [0230]  | DLISTL [D402]     |                      |
| SDMCTL [022F]  | DMACTL [D400]     |                      |
| CHBAS [02F4]   | CHBASE [D409]     |                      |
| CHACT [02F3]   | CHACTL [D401]     |                      |
| GPRIOR [026F]  | PRIOR [D01B]      |                      |
| COLOR0 [02C4]  | COLPFO [D016]     | Attract mode.        |
| COLOR1 [02C5]  | COLPF1 [D017]     |                      |
| COLOR2 [02C6]  | COLPF2 [D018]     |                      |
| COLOR3 [02C7]  | COLPF3 [D019]     |                      |
| COLOR4 [02C8]  | COLBK [D01A]      |                      |
| PCOLOR0 [02C0] | COLPM0 [D012]     |                      |
| PCOLOR1 [02C1] | COLPM1 [D013]     |                      |
| PCOLOR2 [02C2] | COLPM2 [D014]     |                      |
| PCOLOR3 [02C3] | COLPM3 [D015]     |                      |
| Constant = 8   | CONSOL [D01F]     | Console speaker off. |

The stage 2 VBLANK process decrements the System Timer 2 CDTMV2 [021A,2] if it is nonzero; if the timer goes from nonzero to zero, then an indirect JSR is performed through CDTMA2 [0228,2].

The stage 2 VBLANK process decrements System Timers 3, 4 and 5 if they are nonzero; the corresponding flags are set to zero for each timer that changes from nonzero to zero.

| Timer | Timer Value     | Timer Flag      |
|-------|-----------------|-----------------|
| 3     | CDTMV3 [021C,2] | CDTMF3 [022A,1] |
| 4     | CDTMV4 [021E,2] | CDTMF4 [022C,1] |
| 5     | CDTMV5 [0220,2] | CDTMF5 [022E,1] |

A character is read from the POKEY keyboard register and stored in CH [02FC], if auto repeat is active.

The stage 2 VBLANK process decrements the keyboard debounce counter if it is not equal to zero, and if no key is pressed.

The stage 2 VBLANK process processes the keyboard auto repeat (see Appendix L, EB).

The stage 2 VBLANK process reads game controller data from the hardware to the RAM data base, as shown below:

| Hardware Register | Data Base Item | Function                            |
|-------------------|----------------|-------------------------------------|
| PORTA [D300]      | STICK0 [0278]  | Joysticks and<br>Paddle Controllers |
|                   | STICK1 [0279]  |                                     |
|                   | PTRIG0 [027C]  |                                     |
|                   | PTRIG1 [027D]  |                                     |
|                   | PTRIG2 [027E]  |                                     |
| PORTB [D301]      | PTRIG3 [027F]  | Joysticks and<br>Paddle Controllers |
|                   | STICK2 [027A]  |                                     |
|                   | STICK3 [027B]  |                                     |
|                   | PTRIG4 [0280]  |                                     |
|                   | PTRIG5 [0281]  |                                     |
|                   | PTRIG6 [0282]  |                                     |
|                   | PTRIG7 [0283]  |                                     |
| POT 0 [D200]      | PADDL0 [0270]  | Paddle Controllers                  |
| POT 1 [D201]      | PADDL1 [0271]  |                                     |
| POT 2 [D202]      | PADDL2 [0272]  |                                     |
| POT 3 [D203]      | PADDL3 [0273]  |                                     |
| POT 4 [D204]      | PADDL4 [0274]  |                                     |
| POT 5 [D205]      | PADDL5 [0275]  |                                     |
| POT 6 [D206]      | PADDL6 [0276]  |                                     |
| POT 7 [D207]      | PADDL7 [0277]  | Joystick triggers.                  |
| TRIG0 [D001]      | STRIG0 [0284]  |                                     |
| TRIG1 [D002]      | STRIG1 [0285]  |                                     |
| TRIG2 [D003]      | STRIG2 [0286]  |                                     |
| TRIG3 [D004]      | STRIG3 [0287]  |                                     |

## MASKABLE INTERRUPTS

An IRQ interrupt causes control to be transferred through the immediate IRQ global RAM vector VIMIRQ [0216]. Ordinarily this vector points to the system IRQ Handler. The Handler performs these following actions:

The IRQ Handler determines a cause for the interrupt by examining the IRQST [D20E] register and the PIA status registers PACTL [D302] and PBCTL [D303]. The interrupt status bit is cleared when it is found. One interrupt event is cleared and processed for each interrupt-service entry. If multiple IRQs are pending, then a separate interrupt will be generated for each pending IRQ, until all are serviced.

The system IRQ interrupt service routine deals with each of the possible IRQ causing events, in the following ways:

- o The 6502 A register is pushed to the stack.
- o If the interrupt is due to serial I/O bus output ready, then clear the interrupt and jump through global RAM vector VSEROR [020C].
- o If the interrupt is due to serial I/O bus input ready, then clear the interrupt and jump through global RAM vector VSERIN [020A].
- o If the interrupt is due to serial I/O bus output complete, then clear the interrupt and jump through global RAM vector VSEROE [020E].
- o If the interrupt is due to POKEY timer #1, then clear the interrupt and jump through global RAM vector VTIMR1 [0210].
- o If the interrupt is due to POKEY timer #2, then clear the interrupt and jump through global RAM vector VTIMR2 [0212].
- o If the interrupt is due to POKEY timer #4, then clear the interrupt. The service routine contains a bug, and falls into the following test.
- o If pressing a keyboard key caused the interrupt (other than [BREAK], [START], [OPTION], or [SELECT]); then clear the interrupt and jump through global RAM vector VKEYBD [0208].
- o If pressing the [BREAK] key caused the interrupt; then clear the interrupt. Set the BREAK flag BRKKEY [0011] to zero, proceed to clear the following:

- Start/stop flag SSFLAG [02FF]
- Cursor inhibit flag CRSINH [02F0]
- Attract mode flag ATTRACT [004D]

Return from the interrupt after restoring the 6502 A register from the stack.

- o If the interrupt is due to the serial I/O bus proceed line; then clear the interrupt, and jump through global RAM vector VPRCED [0202].
- o If the interrupt is due to the serial I/O bus interrupt line, then clear the interrupt and jump through global RAM vector VINTER [0204].
- o If the interrupt is due to a 6502 BRK instruction, then jump through global RAM vector VBREAK [0206].
- o If none of the above, restore the 6502 A register and return from the interrupt (RTI).

## INTERRUPT INITIALIZATION

The interrupt subsystem completely reinitializes itself whenever the system is powered up or the [SYSTEM.RESET] key is pressed. The OS clears the hardware registers, and sets the interrupt global RAM vectors to the following configurations:

| Vector        | Type | Function                              |
|---------------|------|---------------------------------------|
| VDSLST [0200] | NMI  | RTI -- ignore interrupt.              |
| VVBLKI [0222] | "    | System stage 1 VBLANK.                |
| CDTMA1 [0226] | "    | SIO timeout timer.                    |
| CDTMA2 [0228] | "    | No system function.                   |
| VVBLKD [0224] | "    | System return from interrupt.         |
| VIMIRQ [0216] | IRQ  | System IRQ processor.                 |
| VSEROR [020C] | "    | SIO.                                  |
| VSERIN [020A] | "    | SIO.                                  |
| VSEROC [020E] | "    | SIO.                                  |
| VTIMR1 [0210] | "    | PLA, RTI -- ignore interrupt.         |
| VTIMR2 [0212] | "    | PLA, RTI -- ignore interrupt.         |
| VTIMR4 [0214] | "    | *** doesn't matter ***                |
| VKEYBD [0208] | "    | System keyboard<br>interrupt handler. |
| VPRCED [0202] | "    | PLA, RTI -- ignore interrupt.         |
| VINTER [0204] | "    | PLA, RTI -- ignore interrupt.         |
| VBREAK [0206] | BRK  | PLA, RTI -- ignore interrupt.         |

Figure 6-2 Interrupt RAM Vector Initialization

System initialization sets the interrupt enable status as follows:

|     |                                                                   |
|-----|-------------------------------------------------------------------|
| NMI | VBLANK enabled, display list disabled.                            |
| IRQ | [BREAK] key and data key interrupts enabled, all others disabled. |

## SYSTEM TIMERS

The OS contains five general purpose software timers, plus an OS-supported frame counter. The timers are 2 bytes in length (lo,hi) and the frame counter RTCLOCK [0012] is three bytes in length (hi,mid,lo). The timers count downward from any nonzero value to zero. Upon reaching zero, they either clear an associated flag, or JSR through a RAM vector. The frame counter counts upward, wrapping to zero when it overflows.

The following table shows the timers and the frame counter characteristics:

| Timer Name       | Flag/Vector   | Use                           |
|------------------|---------------|-------------------------------|
| * CDTMV1 [0218]  | CDTMA1 [0226] | 2-byte vector -- SIO timeout. |
| CDTMV2 [021A]    | CDTMA2 [0228] | 2-byte vector                 |
| CDTMV3 [021C]    | CDTMF3 [022A] | 1-byte flag                   |
| CDTMV4 [021E]    | CDTMF4 [022C] | 1-byte flag                   |
| CDTMV5 [0220]    | CDTMF5 [022E] | 1-byte flag                   |
| * RTCLOCK [0012] |               | 3-byte frame counter.         |

\* These two timers are maintained as part of every VBLANK interrupt (stage 1 process). The other timers are subject to the critical section test (stage-2 process), that can defer their updating to a later VBLANK interrupt.

## USAGE NOTES

This subsection describes the techniques you need to know in order to utilize interrupts in conjunction with the operating system.

## POKEY Interrupt Mask

ANTIC (display-list and vertical-blank) and PIA (interrupt and proceed lines) interrupts can be masked directly (see the Hardware Manual). However, eight bits of a single byte IRGEN [D20E] mask the POKEY interrupts ([BREAK] key, data key, serial input ready, serial output ready, serial output done and timers 1,2 and 4).

IRGEN is a write-only register. Thus, we must maintain a current value of that register in RAM in order to update individual mask bits selectively, while not changing other bits. The name of the variable used is POKMSK [0010], and it is used as shown in the examples below:

### ; EXAMPLE OF INTERRUPT ENABLE

```
SEI ; TO AVOID CONFLICT WITH IRQ ...
LDA POKMSK ; ... PROCESSOR WHICH ALTERS VAR.
ORA #$xx ; ENABLE BIT(S).
STA POKMSK
STA IRGEN ; TO HARDWARE REG TOO.
CLI
```

### ; EXAMPLE OF INTERRUPT DISABLE

```
SEI ; TO AVOID CONFLICT WITH IRQ ...
LDA POKMSK ; ... PROCESSOR WHICH ALTERS VAR.
AND #$FF-xx ; DISABLE BIT(S).
STA POKMSK
STA IRGEN ; TO HARDWARE REGISTER TOO.
CLI
```

Figure 6-3 POKEY Interrupt Mask Example

Note that the OS IRQ service routine uses and alters POKMSK, so alterations to the variable must be done with interrupts inhibited. If done at the interrupt level there is no problem, as the I bit is already set; if done at a background level then the SEI and CLI instructions should be used as shown in the examples.

## Setting Interrupt and Timer Vectors

Because vertical-blank interrupts are generally kept enabled so that the frame counter RTCLOCK is maintained accurately, there is a problem with setting the VBLANK vectors (VVBLKI and VVBLKD) or the timer values (CDTMV1 through CDTMV5) directly. A VBLANK interrupt could occur when only one byte of the two-byte value had been updated, leading to undesired consequences. For this reason,

the SETVBV [E45F] routine is provided to perform the desired update in safe manner. The calling sequence is shown below:

A = update item indicator  
1 - 5 for timers 1 - 5.  
6 for immediate VBLANK vector VVBLKI.  
7 for deferred VBLANK vector VVBLKD.  
X = MSB of value to store.  
Y = LSB of value to store.

JSR SETVBV

The A, X and Y registers can be altered.  
The display list interrupt will always be disabled on return, even if enabled upon entry.

It is possible to fully process a vertical-blank interrupt during a call to this routine.

When working with the System Timers, the vectors for timers 1 and 2 and the flags for timers 3, 4 and 5 should be set while the associated timer is equal to zero, then the timer should be set to its (nonzero) value.

#### Stack Content at Interrupt Vector Points

The following table shows the stack content at every one of the RAM interrupt vector points:

## RAM STACK CONTENT

| INTERRUPT VECTOR | DESCRIPTION        | OS RETURN CONTROL          |
|------------------|--------------------|----------------------------|
| VDSLST [0200]    | Display list       | return, P                  |
| VVBLKI [0222] *  | VBLANK immediate   | return, P, A, X, Y         |
| CDTMA1 [0226]    | System Timer 1     | return, P, A, X, Y, return |
| CDTMA2 [0228]    | System Timer 2     | return, P, A, X, Y, return |
| VVBLKD [0224] *  | VBLANK defer.      | return, P, A, X, Y         |
| VIMIRQ [0216] *  | IRQ immediate      | return, P, A               |
| VSEROR [020C] *  | Serial out ready   | return, P, A               |
| VSERIN [020A] *  | Serial in ready    | return, P, A               |
| VSEROC [020E] *  | Serial out compare | return, P, A               |
| VTIMR1 [0210]    | POKEY timer 1      | return, P, A               |
| VTIMR2 [0212]    | POKEY timer 2      | return, P, A               |
| VTIMR4 [0214]    | POKEY timer 4      | return, P, A               |
| VKEYBD [0208] *  | Keyboard data      | return, P, A               |
| VPRSED [0202]    | Serial proceed     | return, P, A               |
| VINTER [0204]    | Serial interrupt   | return, P, A               |
| VBREAK [0206]    | BRK instruction    | return, P, A               |

Figure 6-4 Interrupt and Timer Vector RAM Stack Content Table

\* The OS initializes these entries at power-up. Improperly changing these vectors will alter system performance.

### Miscellaneous Considerations

The following paragraphs list a set of miscellaneous considerations for the writer of an interrupt service routine.

#### Restrictions on Clearing of "I" Bit

Display list, immediate vertical-blank and System Timer #1 routines should not clear the 6502 I bit. If the NMI leading to one of these routines occurred while an IRQ was being processed, then clearing the I bit will cause the IRQ to re-interrupt with an unknown result.

The OS VBLANK processor carefully checks this condition after the stage 1 process and before the stage 2 process.

#### Interrupt Process Time Restrictions

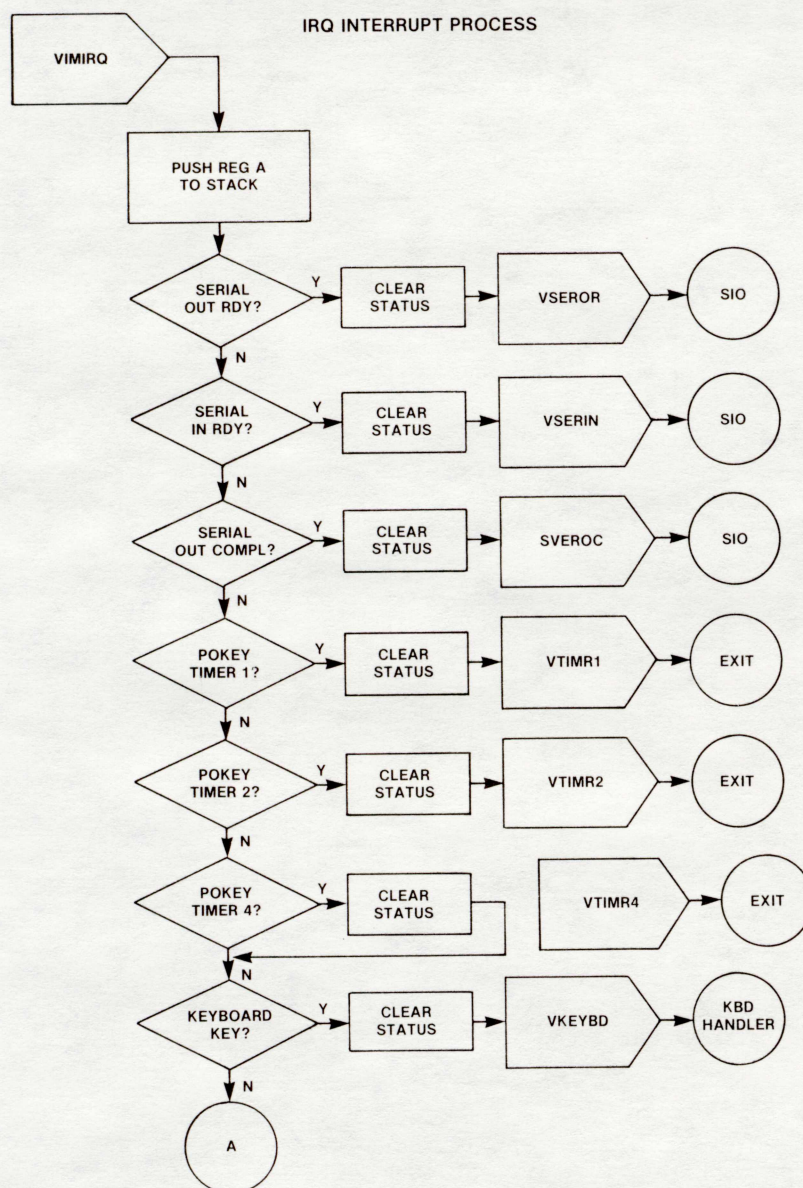
You should not write an interrupt routine that exceeds 400 msec. when added to the stage 1 VBLANK, if the serial I/O is being used. The SID sets the CRITIC flag while serial bus I/O is in progress.

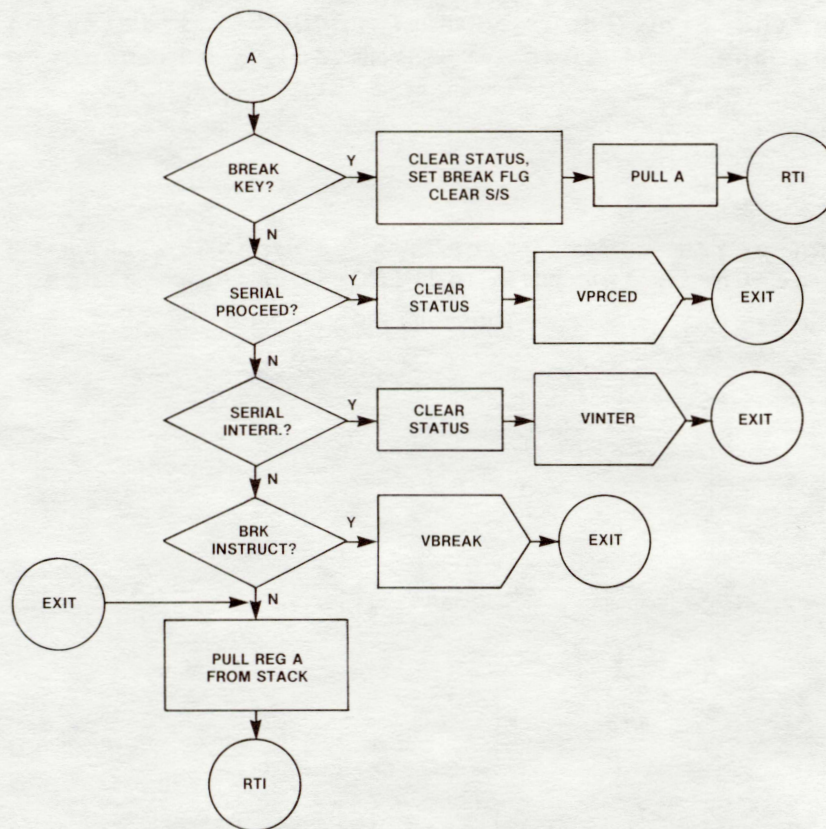
## Interrupt Delay Due to "WAIT FOR SYNC"

Whenever a key is read from the keyboard, the Keyboard Handler sets WSYNC [D40A] repeatedly while generating the audible click on the console speaker. A problem occurs when interrupts are generated during the wait-for-sync period; the processing of such interrupts will be delayed by one horizontal scan line. This condition cannot be prevented. You can work around the condition by examining the line count VCOUNT [D40B] and delaying interrupt processing by one line when no WSYNC delay has occurred.

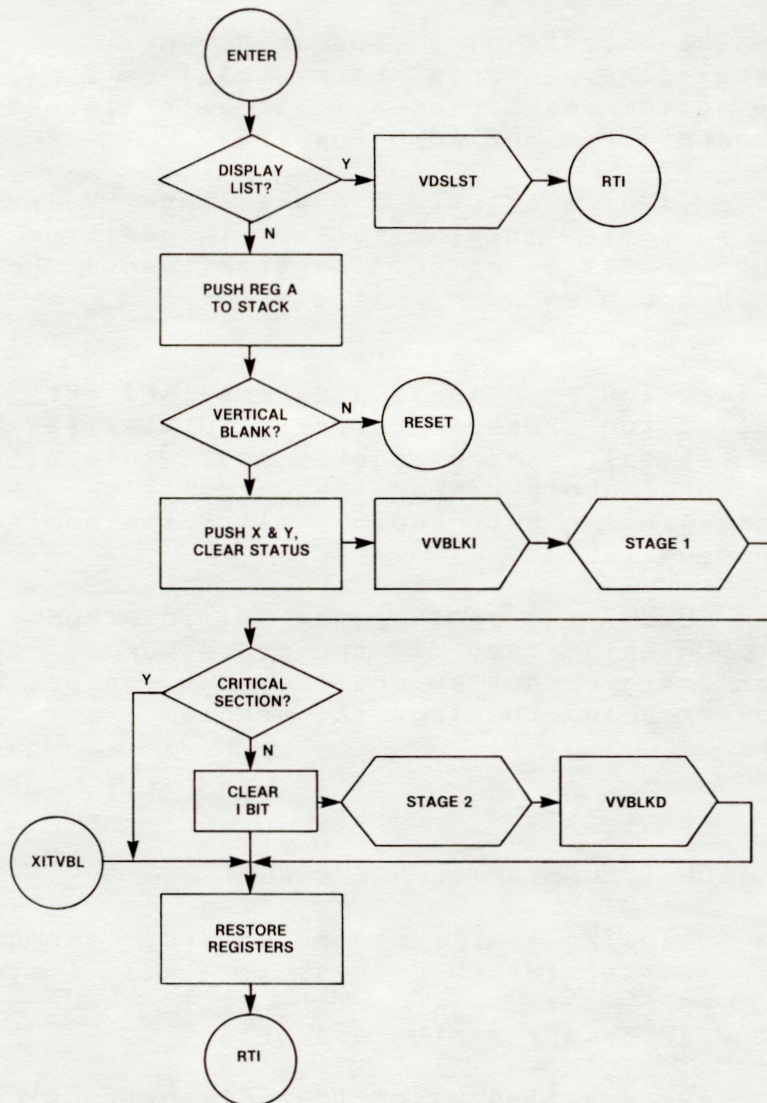
## FLOWCHARTS

The following pages contain process flowcharts showing the main events that occur in the NMI and IRQ interrupt processes.





# NMI INTERRUPT PROCESS



## 7 SYSTEM INITIALIZATION

Section 7 discusses the details of the power-up and system reset processes. The power-up process will be explained first, and then the system reset process will be explained in terms of its differences from the power-up process.

Both power-up (also called coldstart) and pressing [SYSTEM.RESET] (warmstart) will cause system initialization. In addition, there are vectors for these processes at E474 (system reset) and E477 (power-up) so that they can be user-initiated.

The power-up initialization process is a superset of the system reset initialization process. Power-up initializes both the OS and user RAM regions, whereas system reset initializes only the OS RAM region. In both cases, the OS calls the outer level software initialization entry points allow the application to initialize its own variables.

Pressing the [SYSTEM.RESET] key produces an NMI interrupt. It does not perform a 6502 chip-reset. If the processor is locked up, the [SYSTEM.RESET] key cannot be sufficient to unlock it, and the system must have power cycled to clear the problem.

### POWER-UP INITIALIZATION (COLDSTART) PROCEDURE

The OS performs the following functions in the order shown, as part of the power-up initialization process:

1. The following 6502 processor states are set:
  - o IRQ interrupts are disabled using the SEI instruction.
  - o The decimal flag is cleared using the CLD instruction.
  - o The stack pointer is set to \$FF.
2. The OS sets the warmstart flag WARMST [0008] to 0 (false).

3. The OS tests to see if a diagnostic cartridge is in the A slot:
  - o Cartridge address BFFC = 00?
  - o The memory at BFFC is not RAM?
  - o Bit 7 of the byte at BFFD = 1?

If all of the above tests are true, then control is passed to the diagnostic cartridge via the vector at BFFE. No return is expected.

4. The OS determines the lowest memory address containing non-RAM, by testing the first byte of every 4K "block" to see if the content can be complemented. If it can be complemented, then the original value is restored and testing continues. If it can't be complemented; then the content is assumed to be the first non-RAM address in the system. The MSB of the address is stored temporarily in TRAMSZ [0006].
5. Zero is stored to all of the hardware register addresses shown below (most of that aren't decoded by the hardware):
  - D000 through D0FF
  - D200 through D2FF
  - D300 through D3FF
  - D400 through D4FF
6. The OS clears RAM from location 0008, to the address determined in step 4, above.
7. The default value for the "noncartridge" control vector DOSVEC [000A] is set to point to the blackboard routine. At the end of initialization, control is passed through this vector if a cartridge does not take control.
8. The coldstart flag COLDST [0244] is set to -1 (local use).
9. The screen margins are set: left margin = 2, right margin = 39, for a 38 character physical line. The maximum line size of 40 characters can be obtained by setting the margins to 0 and 39. The OS insets the left margin because the two leftmost columns of the video picture on many television sets are not entirely visible on the screen.
10. The interrupt RAM vectors VDSLST [0200] through VVBLKD [0224] are initialized. See Section 6 for the initialization values.
11. Portions of the OS RAM are set to their required nonzero values as shown below:

- o The [BREAK] key flag BRKKEY [0011] = -1 (false).
  - o The top of memory pointer MEMTOP [02E5] = the lowest non-RAM address (from step 4); MEMTOP will be altered later when the Screen Editor is opened in step 15.
  - o The bottom of memory pointer MEMLO [02E7] = 0700; MEMLO can be changed later if there is either a diskette- or cassette-boot operation.
  - o The following resident routines are called for initialization:
    - Screen Editor
    - Display Handler
    - Keyboard Handler
    - Printer Handler
    - Cassette Handler
    - Central I/O Monitor (CIO)
    - Serial I/O Monitor (SIO)
    - Interrupt processor
  - o The [START] key is checked, and if pressed, the cassette-boot request flag CKEY [004A] is set.
12. 6502 IRQ interrupts are enabled using the CLI instruction.
  13. The device table HATABS [031A] is initialized to point to the resident handlers. See Section 9 for information relating to the Device Handler table.
  14. The cartridge slot addresses for cartridges B and A are examined to determine if cartridges are inserted, if RAM does not extend into the cartridge address space.
 

If the content of location 9FFC is zero, then a JSR is executed through the vector at 9FFE, thus initializing cartridge "B". The cartridge is expected to return.

If the content of location BFFC is zero, then a JSR is executed through the vector at BFFE, thus initializing cartridge "A". The cartridge is expected to return.
  15. IOCB #0 is set up for an OPEN of the Screen Editor (E) and the OPEN is performed. The Screen Editor will use the highest portion of RAM for the screen and will adjust MEMTOP accordingly. If this operation should fail, the entire initialization process is repeated.
  16. A delay is effected to assure that a VBLANK interrupt has occurred. This is done so that the screen will be established before continuing.
  17. If the cassette-boot request flag is set (see step 11 above), then a cassette-boot operation is attempted. See Section 10

for details of the cassette-boot operation.

18. If any of the three conditions stated below exists, an attempt is made to boot from the disk.

There are no cartridges in the slots.

Cartridge B is inserted and bit 0 of 9FFD is 1.

Cartridge A is inserted and bit 0 of BFFD is 1.

See Section 10 for details of the diskette-boot operation.

19. The coldstart flag COLDST is reset to indicate that the coldstart process went to completion.
20. The initialization process is now complete, and the controlling application is now determined via the remaining steps.

If there is an A cartridge inserted and bit-2 of BFFD is 1, then a JMP is executed through the vector at BFFA.

Or, if there is a B cartridge inserted and bit-2 of 9FFD is 1, then a JMP is executed through the vector at 9FFA.

Or, a jump is executed through the vector DOSVEC that can point to the blackboard routine (default case), cassette booted software or diskette booted software. DOSVEC can be altered by the booted software as explained in Section 10.

#### SYSTEM RESET INITIALIZATION (WARMSTART) PROCEDURE

The functions listed below are performed, in the order shown, as part of the system reset initialization process:

- A. Same as power-up step 1.
- B. The warmstart flag WARMST [0008] is set to -1 (true).
- C. Same as power-up steps 3 through 5.
- D. OS RAM is zeroed from locations 0200-03FF and 0010-007F.
- E. Same as power-up steps 9 through 16.
- F. If a cassette-boot was successfully completed during the power-up initialization, then a JSR is executed through the vector CASINI [0002]. See Section 10 for details of the cassette-boot process.

G. Same as power-up step 18, except instead of booting the diskette software, a JSR is executed through the vector DOSINI [000C] if the diskette-boot was successfully completed during the Power-up initialization. See Section 10 for details of the diskette-boot process.

H. Same as power-up steps 19 and 20.

Note that the initialization procedures and main entries for all software entities are executed at every system reset as well as at power up (see steps 14, 17, 18, 20, F and G). If the user-supplied initialization/startup code must behave differently in response to system reset than it does to power-up, then the warmstart flag WARMST [0008] should be interrogated; WARMST = 0 means power-up entry, else system reset entry.

## 8 FLOATING POINT ARITHMETIC PACKAGE

This section describes the BCD floating point (FP) package that is resident in the OS ROM in both the models 400 and 800.

The floating point package maintains numbers internally as 6-byte quantities: a 5-byte (10 BCD digit) mantissa with a 1-byte exponent. BCD internal representation was chosen so that decimal division would not lead to the rounding errors typically found in binary representation implementations.

The package provides the following operations:

- ASCII to FP conversion.
- FP to ASCII conversion.
- Integer to FP conversion.
- FP to integer conversion.
- FP add, subtract, multiply, and divide.
- FP logarithm, exponentiation, and polynomial evaluation.
- FP zero, load, store, and move.

A floating point operation is performed by calling one of the provided routines (each at a fixed address in ROM) after having set one or more floating point pseudo registers in RAM. The result of the desired operation will also involve floating point pseudo registers. The primary pseudo registers are described below and their addresses given within the square brackets:

FRO [00D4] = 6-byte internal form of FP number.  
 FR1 [00E0] = 6-byte internal form of FP number.  
 FLPTR [00FC] = 2-byte pointer (lo,hi) to a FP.  
                   number.  
 INBUFF [00F3] = 2-byte pointer (lo,hi) to an ASCII text  
                   buffer.  
 CIX [00F2] = 1-byte index, used as offset to buffer  
                   pointed to by INBUFF.  
 LBUFF [0580] = result buffer for the FASC routine.

## FUNCTIONS/CALLING SEQUENCES

Descriptions of these floating point routines assume that a pseudo register is not altered by a given routine. The numbers in square brackets [xxxx] are the ROM addresses of the routines.

### ASCII to Floating Point Conversion (AFP)

Function: This routine takes an ASCII string as input and produces a floating point number in internal form.

Calling sequence:

INBUFF = pointer to buffer containing the ASCII  
           representation of the number.  
 CIX = the buffer offset to the first byte of the ASCII  
       number.

JSR       AFP [D800]  
 BCS       first byte of ASCII number is invalid

FRO = floating point number.  
 CIX = the buffer offset to the first byte after the ASCII  
       number.

Algorithm: The routine takes bytes from the buffer until it encounters a byte that cannot be part of the number. The bytes scanned to that point are then converted to a floating point number. If the first byte encountered is invalid, the carry bit is set as a flag.

### Floating Point to ASCII Conversion (FASC)

Function: This routine converts a floating point number from internal form to its ASCII representation.

Calling sequence:

FRO = floating point number.

JSR        FASC [D8E6]

INBUFF = pointer to the first byte of the ASCII number.  
The last byte of the ASCII representation has the most significant bit (sign bit) set; no EOL follows.

Algorithm: The routine converts the number from its internal floating point representation to a printable form (ATASCII). The pointer INBUFF will point to part of LBUFF, where the result is stored.

#### Integer to Floating Point Conversion (IFP)

Function: This routine converts a 2-byte unsigned integer (0 to 65535) to floating point internal representation.

Calling sequence:

FRO = integer (FRO+0 = LSB, FRO+1 = MSB).

JSR        IFP [D9AA]

FRO = floating point representation of integer.

#### Floating Point to Integer Conversion (FPI)

Function: This routine converts a positive floating point number from its internal representation to the nearest 2-byte integer.

Calling sequence:

FRO = floating point number.

JSR        FPI [D9D2]

BCS        FP number is negative or  $\geq 65535.5$

FRO = 2-byte integer (FRO+0 = LSB, FRO+1 = MSB).

Algorithm: The routine performs true rounding, not truncation, during the conversion process.

### Floating Point Addition (FADD)

Function: This routine adds two floating point numbers and checks the result for out-of-range.

Calling sequence:

FRO = floating point number.  
FR1 = floating point number.  
  
JSR        FADD [DA66]  
BCS        out-of-range result.  
  
FRO = result of  $FRO + FR1$ .  
FR1 is altered.

### Floating Point Subtraction (FSUB)

Function: This routine subtracts two floating point numbers and checks the result for out-of-range.

Calling sequence:

FRO = floating point minuend.  
FR1 = floating point subtrahend.  
  
JSR        FSUB [DA60]  
BCS        out-of-range result.  
  
FRO = result of  $FRO - FR1$ .  
FR1 is altered.

### Floating Point Multiplication (FMUL)

Function: This routine multiplies two floating point numbers and checks the result for out-of-range.

Calling sequence:

FRO = floating point multiplier.  
FR1 = floating point multiplicand.  
  
JSR        FMUL [DADB]  
BCS        out-of-range result.  
  
FRO = result of  $FRO * FR1$ .  
FR1 is altered.

### Floating Point Division (FDIV)

Function: This routine divides two floating point numbers and checks for division by zero and for result out-of-range.

Calling sequence:

FRO = floating point dividend.  
FR1 = floating point divisor.

JSR        FDIV [DB28]  
BCS        out-of-range result or divisor is zero.

FRO = result of FRO / FR1.  
FR1 is altered.

### Floating Point Logarithms (LOG and LOG10)

Function: These routines take the natural or base 10 logarithms of a floating point number.

Calling sequence:

FRO = floating point number.

JSR        LOG [DECD] for natural logarithm  
or  
JSR        LOG10 [DED1] for base 10 logarithm  
BCS        negative number or overflow.

FRO = floating point logarithm.  
FR1 is altered.

Algorithm: Both logarithms are first computed as base 10 logarithms using a 10 term polynomial approximation; the natural logarithm is computed by dividing the base 10 result by the constant LOG10(e).

The logarithm of a number Z is computed as follows:

$F * (10 ** Y) = Z$  where  $1 \leq F < 10$  (normalization).  
 $L = \text{LOG10}(F)$  by 10 term polynomial approximation.  
 $\text{LOG10}(Z) = Y + L$ .     $\text{LOG}(Z) = \text{LOG10}(Z) / \text{LOG10}(e)$ .

NOTE: This routine does not return an error if the number input is zero; the LOG10 result in this case is approximately -129.5, which is not useful.

## Floating Point Exponentiation (EXP and EXP10)

Function: This routine exponentiates.

Calling sequence:

```
 FRO = floating point exponent (Z).
or JSR EXP [DDCO] for e ** Z
 JSR EXP10 [DDCC] for 10 ** Z
 BCS overflow.

 FRO = floating point result.
 FR1 is altered.
```

Algorithm: Both exponentials are computed internally as base 10, with the base e exponential using the identity:  
 $e ** X = 10 ** (X * \text{LOG10}(e))$ .

The base 10 exponential is evaluated in two parts using the identity:

$10 ** X = 10 ** (I + F) = (10 ** I) * (10 ** F)$  -- where I is the integer portion of X and F is the fraction.

The term  $10 ** F$  is evaluated using a polynomial approximation, and  $10 ** I$  is a straightforward modification to the floating point exponent.

## Floating Point Polynomial Evaluation (PLYEVL)

Function: This routine performs an n degree polynomial evaluation.

Calling sequence:

```
 X,Y = pointer (X = LSB) to list of FP coefficients (A(i))
 ordered from high order to low order (six bytes per
 coefficient).
 A = number of coefficients in list.
 FRO = floating point independent variable (Z).

 JSR PLYEVL [DD40]
 BCS overflow or other error.

 FRO = result of $A(n)*Z**n + A(n-1)*Z**n-1 \dots + A(1)*Z + A(0)$.
 FR1 is altered.
```

Algorithm: The polynomial  $P(Z) = \text{SUM}(i=0 \text{ to } n) (A(i)*Z**i)$  is computed using the standard method shown below:

$$P(Z) = (\dots (A(n)*Z + A(n-1))*Z + \dots + A(1))*Z + A(0)$$

#### Clear FRO (ZFRO)

Function: This routine sets the contents of pseudo register FRO to all zeros.

Calling sequence:

```
JSR ZFRO [DA44]
```

FRO = zero.

#### Clear Page Zero Floating Point Number (ZF1)

Function: This routine sets the contents of a zero-page floating point number to all zeroes.

Calling sequence:

X = Zero-page address of FP number to clear.

```
JSR ZF1 [DA46]
```

Zero-page FP number(X) = zero.

#### Load Floating Point Number to FRO (FLDOR and FLDOP)

Function: These routines load pseudo register FRO with the floating point number specified by the calling sequence.

Calling sequences:

X,Y = pointer (X = LSB) to FP number.

```
JSR FLDOR [DD89]
```

or

FLPTR = pointer to FP number.

```
JSR FLDOP [DD8D]
```

FRO = floating point number (in either case).

FLPTR = pointer to FP number (in either case).

Load Floating Point Number to FR1 (FLD1R and FLD1P)

Function: These routines load pseudo register FR1 with the floating point number specified by the calling sequence.

Calling sequences:

As in prior description, except the result goes to FR1 instead of FRO. FLD1R [DD98] and FLD1P [DD9C].

Store Floating Point Number From FRO (FSTOR and FSTOP)

Function: These routines store the contents of pseudo register FRO to the address specified by the calling sequence:

Calling sequence:

As in prior descriptions, except the floating point number is stored from FRO rather than loaded to FRO. FSTOR [DDA7] and FSTOP [DDAB].

Move Floating Point Number From FRO to FR1 (FMOVE)

Function: This routine moves the floating point number in FRO to pseudo register FR1.

Calling sequence:

JSR FMOVE [DDB6]

FR1 = FRO (FRO remains unchanged).

## RESOURCE UTILIZATION

The floating point package uses the following RAM locations in the course of performing the functions described in this section:

00D4 through 00FF  
057E through 05FF

All of these locations are available for program coding if your program does not call the floating point package.

## IMPLEMENTATION DETAILS

Floating point numbers are maintained internally as 6-byte quantities, with 5 bytes (10 BCD digits) of mantissa and 1 byte of exponent. The mantissa is always normalized such that the most significant byte is nonzero (note "byte" and not "BCD digit").

The most significant bit of the exponent byte provides the sign for the mantissa; 0 for positive and 1 for negative. The remaining 7 bits of the exponent byte provide the exponent in excess 64 notation. The resulting number represents powers of 100 decimal (not powers of 10). This storage format allows the mantissa to hold 10 BCD digits when the value of the exponent is an even power of 10, and 9 BCD digits when the value of the exponent is an odd power of 10.

The implied decimal point is always to the immediate right of the first byte. An exponent less than 64 indicates a number less than 1. An exponent equal to or greater than 64 represents a number equal to or greater than 1.

Zero is represented by a zero mantissa and a zero exponent. To test for a result from any of the standard routines; test either the exponent or the first mantissa byte for zero.

The absolute value of floating point numbers must be greater than  $10^{*-98}$ , and less than  $10^{*+98}$ , or be equal to zero. There is perfect symmetry between positive and negative numbers with the exception that negative zero is never generated.

The precision of all computations is maintained at 9 or 10 decimal digits, but accuracy is somewhat less for those functions involving polynomial approximations (logarithm and exponentiation). Also, the problems inherent in all floating point systems are present here; for example: subtracting two very nearly equal numbers, adding numbers of disparate magnitude, or successions of any operation, will all result in a loss of significant digits. An analysis of the data range and the order of evaluation of expressions may be required for some types of applications.

The examples below compare floating point numbers with their internal representations, as an aid to understanding storage format. All numbers prior to this point have been expressed in decimal notation, but these examples will use hexadecimal notation. Note that 64 decimal (the excess number of the exponent) is 40 when expressed in hexadecimal:

Number:  $+0.02 = 2 * 10^{*-2} = 2 * 100^{*-1}$   
Stored: 3F 02 00 00 00 00 (FP exponent = 40 - 1)

Number:  $-0.02 = -2 * 10^{*-2} = -2 * 100^{*-1}$   
Stored: BF 02 00 00 00 00 (FP exponent = 80 + 40 - 1)

Number:  $+37.0 = 3.7 * 10^{**1} = 37 * 100^{**0}$

Stored: 40 37 00 00 00 00 (FP exponent =  $40 + 0$ )

Number:  $-4.60312486 * 10^{**11} = -46.03... * 100^{**5}$

Stored: C5 46 03 01 24 86 (FP exponent =  $80 + 40 + 5$ )

Number: 0.0

Stored: 00 00 00 00 00 00 (special case)

## 9 ADDING NEW DEVICE HANDLERS/PERIPHERALS

This section describes the interface requirements for a nonresident Device Handler that is to be accessed via the Central I/O utility (CIO). The Serial bus I/O utility (SIO) interface is defined for those handlers that utilize the Serial I/O bus.

The I/O subsystem is organized with three levels of software between you and your hardware: The CIO, the individual device handlers, and the SIO.

The CIO performs the following functions:

- Logical device name to Device Handler mapping (on OPEN).

- I/O Control Block (IOCB) maintenance.

- Logical record handling.

- User buffer handling.

The device handlers are below CIO. They perform the following functions:

- Device initialization on power-up and system reset.

- Device-dependent support of OPEN and CLOSE commands.

- Byte-at-a-time data input and output.

- Device-dependent special operations.

- Device-dependent command support.

- Device data buffer management.

The SIO is at the bottom level (for Serial I/O bus peripheral handlers). It performs the following functions:

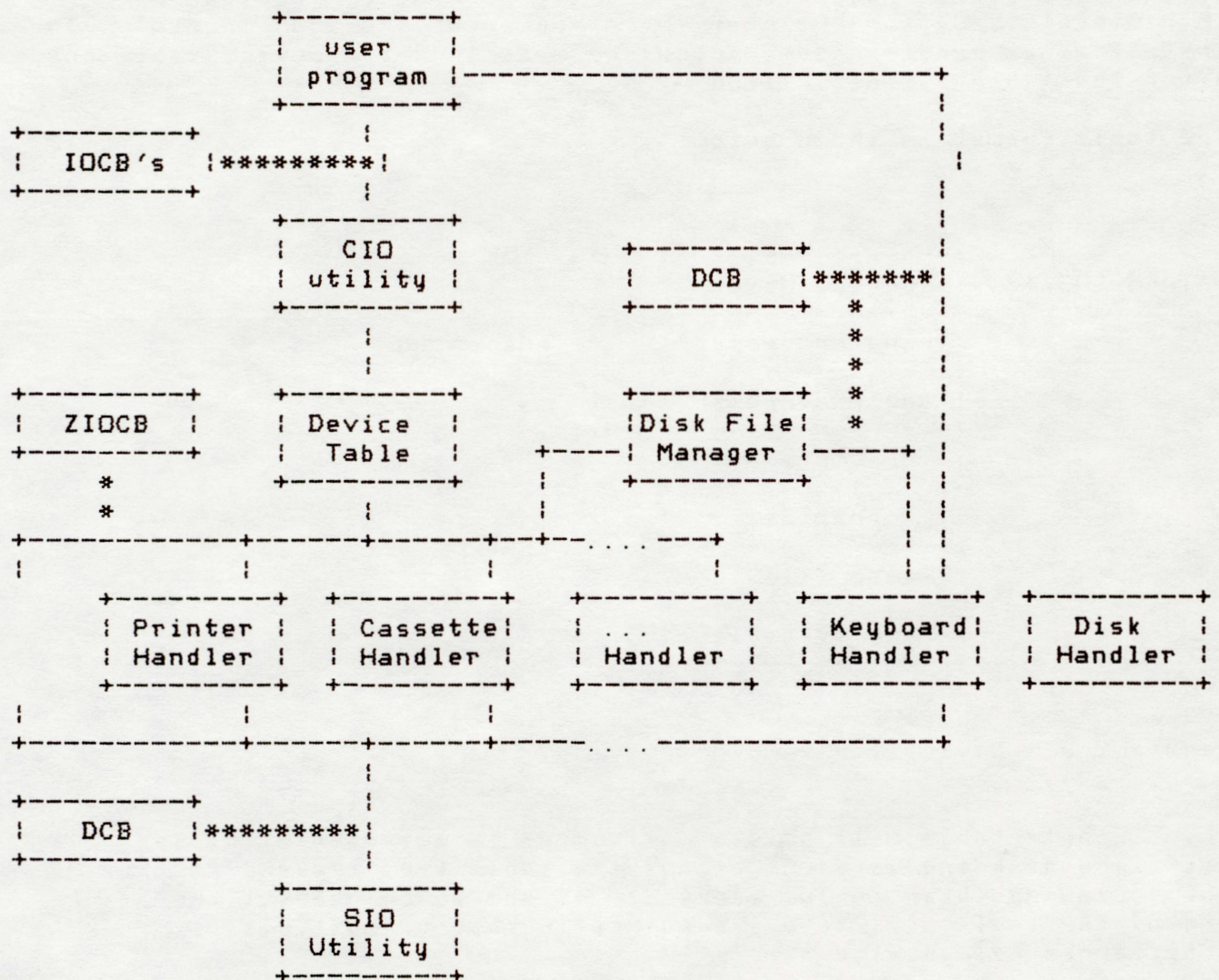
- Control of all Serial bus I/O, conforming to the bus protocol.

- Bus operation retries on errors.

- Return of unified error statuses on error conditions.

A separate control structure is used for communication at each interface, as follows:

|             |                            |
|-------------|----------------------------|
| User/CIO    | I/O Control Block (IOCB)   |
| CIO/Handler | Zero-page IOCB (ZIOCB)     |
| Handler/SIO | Device Control Block (DCB) |



Where: ---- shows a control path.

\*\*\*\* shows the data structure required for a path.

Note the following:

1. The Keyboard/Display/Screen Editor handlers don't use SIO.
2. The Diskette Handler cannot be called directly from CIO.
3. The DCB is shown twice in the diagram.

Figure 9-1 I/O Subsystem Flow Diagram

## DEVICE TABLE

The device table is a RAM-resident table that contains the single-character device name (e.g. K, D, C, etc). and the handler address for each of the handlers known to CIO. The table is initialized to contain entries for the following resident handlers: Keyboard (K), Display (S), Screen Editor (E), Cassette (C), and Printer (P) at power-up and system reset. To install a new handler, some procedure must insert a device table entry after the table is initialized.

The table format is shown below:

```
HATABS [031A] +-----+ +-
 | device name | |
 +-----+ |
 | handler vector | +- one entry
 +-----+ |
 | table address | |
 +-----+ +-
 | more |
 = =
 | entries |
 +-----+
 | zero fill to |
 = =
 | end of table |
 +-----+
```

Figure 9-2 Device Table Format

This 38-byte table will hold a maximum of 12 entries, with the last 2 bytes being zero. CIO scans the table from the end to the beginning (high to low address); so the entry nearest the end of the table will take precedence in case of multiple occurrences of a device name..

The device name for each entry is a single ATASCII character, and the handler address points to the handler's vector table, that will be described in the following section.

## CIO/HANDLER INTERFACE

This section describes the interface between the Central I/O utility and the individual device handlers that are represented in the Device Table (as described in the preceding section).

## Calling Mechanism

Each handler has a vector table as shown below:

|                    |                |
|--------------------|----------------|
| +-----+            |                |
| + OPEN vector +    | (low address)  |
| +-----+            |                |
| + CLOSE vector +   |                |
| +-----+            |                |
| + GETBYTE vector + |                |
| +-----+            |                |
| + PUTBYTE vector + |                |
| +-----+            |                |
| + GETSTAT vector + |                |
| +-----+            |                |
| + SPECIAL vector + |                |
| +-----+            |                |
| + JMP init code +  |                |
| +-----+            |                |
| +-----+            | (high address) |

Figure 9-3 Handler Vector Table

The device table entry for the handler points to the first byte of the vector table.

The first six entries in the table are vectors (lo,hi) that contain the address - 1 of the handler routine that handles the indicated function. The seventh entry is a 6502 JMP instruction to the handler initialization routine. CIO uses only the addresses contained in this table for handler entry. Each user/CIO command translates to one or more calls to one of the handler entries defined in the vector table.

The vector table provides the handler addresses for certain fixed functions to be performed to CIO. In addition, operation parameters also must be passed for most functions. Parameter passing is accomplished using the 6502 A, X, and Y registers and an IOCB in page 0 named ZIOCB [0020]. In general, register A is used to pass data, register X contains the index to the originating IOCB, and register Y is used to pass status information to CIO. The zero-page IOCB, is a copy of the originating IOCB; but in the course of processing some commands, CIO can alter the buffer address and buffer length parameters in ZIOCB, but not in the originating IOCB (see Section 5 for information relating to the originating IOCB).

See Appendix B for the standard status byte values to be returned to CIO in register Y.

The following sections describe the CIO/handler interface for each of the vectors in the handler vector table.

## Handler Initialization

NOTE: This entry doesn't appear to have any function for nonresident handlers due to a bug in the current OS -- the device table is cleared in response to system reset as well as power-up. This prevents this entry point from ever being called. The rest of this section discusses the intended use of this entry point. Conformation would be in order to allow compatibility with possible corrected versions of the OS in the future.

The entry was to have been called on all occurrences of power-up and system reset; the handler is to perform initialization of its hardware and RAM data using a routine that assures proper processing of all CIO commands that follow.

## Functions Supported

This section describes the functions associated with the first six vectors from the handler vector table. This section also presents a brief, device-independent description of the CIO/handler interface and recommended actions for each function vector.

### OPEN

This entry is called in response to an OPEN command to CIO. The handler is expected to validate the OPEN parameters and perform any required device initialization associated with a device OPEN.

At handler entry, the following parameters can be of interest:

X = index to originating IOCB.

Y = \$92 (status = function not implemented by handler).

ICDNOZ [0021] = device number (1-4, for multiple device handlers).

ICBALZ/ICBAHZ [0024/0025] = address of device/filename specification.

ICAX1Z/ICAX2Z [002A/002B] = device-specific information.

The handler attempts to perform the indicated OPEN and indicates the status of the operation by the value of the Y register. The responsibility for checking for multiple OPENS to

the same device or file, where it is illegal, lies with the handler.

## CLOSE

This vector table entry is called in response to a CLOSE command to CIO. The handler is expected to release any held resources that relate specifically to that device/filename, and for output files to:

- 1) send any data remaining in handler buffers to the device,
- 2) mark the end of file
- 3) update any associated directories, allocation maps, etc.

At handler entry, the following parameters can be of interest:

X = index to originating IOCB.

Y = \$92 (status = function not implemented by handler).

ICDNOZ [0021] = device number (1-4, for multiple device handlers).

ICAX1Z/ICAX2Z [002A/002B] = device-specific information.

The handler attempts to perform the indicated CLOSE and indicates the status of the operation by the value of the Y register.

CIO releases the associated IOCB after the handler returns, regardless of the operation status value.

## GETBYTE

This vector table entry is called in response to a GET CHARACTERS or GET RECORD command to CIO. The handler is expected to return a single byte in the A register, or return an error status in the Y register.

At handler entry, the following parameters can be of interest:

X = index to originating IOCB.

Y = \$92 (status = function not implemented by handler).

ICDNOZ [0021] = device number (1-4, for multiple device handlers).

ICAX1Z/ICAX2Z [002A/002B] = device-specific information.

The handler will obtain a data byte directly from the device or from a handler-maintained buffer and return to CIO with the byte in the A register and the operation status in the Y register.

Handlers that do not have short timeouts associated with the reading of data (such as the Keyboard and Cassette Handlers), must monitor the [BREAK] key flag BRKKEY [0011] and return with a status of \$80 when a [BREAK] condition occurs. See Appendix L, E5; and Section 12 for a discussion of [BREAK] key monitoring.

CIO checks for reads from device/files that have not been opened or have been opened for output only; the handler will not be called in those cases.

## PUTBYTE

This entry is called in response to a PUT CHARACTERS or PUT RECORD command to CIO. The handler is expected to accept a single byte in the A register or return an error status in the Y register.

At handler entry, the following parameters can be of interest:

- X = index to originating IOCB.
- Y = \$92 (status = function not implemented by handler).
- A = data byte.

ICDNOZ [0021] = device number (1-4, for multiple device handlers).

ICAX1Z/ICAX2Z [002A/002B] = device-specific information.

The handler sends the data byte directly to the device, or to a handler-maintained buffer, and returns to CIO with the operation status in the Y register. If a handler-maintained buffer fills, the handler will send the buffered data to the device before returning to CIO.

CIO checks for WRITES to device/files that have not been opened, or have been opened for input only. The handler will not be called in those cases.

Now that the normal operation of PUTBYTE has been defined, a special case must be added. Any handler that will operate within the environment of the ATARI 8K BASIC language interpreter has a different set of rules. Because BASIC can call the handler PUTBYTE entry directly, without going through CIO, the zero-page IOCB (ZIOCB) can or may not have a relation to the PUTBYTE call. Therefore, the handler must use the outer level IOCB to obtain any information that would normally be obtained from ZIOCB. Note also that the OPEN protection normally provided by CIO is bypassed (i.e. PUTBYTE to a non-OPEN device/file and PUTBYTE to a read-only OPEN).

## GETSTAT

This entry is called in response to a GET STATUS command to CIO. The handler is expected to return four bytes of status to memory or return an error status in the Y register.

At handler entry, the following parameters can be of interest:

X = index to originating IOCB. Y = \$92 (status = function not implemented by handler).

ICDNOZ [0021] = device number (1-4, for multiple device handlers).  
ICBALZ/ICBAHZ [0024/0025] = address of device/filename specification.  
ICAX1Z/ICAX2Z [002A/002B] = device-specific information.

The handler gets device status information from the device controller and puts the status bytes in DVSTAT [02EA] through DVSTAT+3, and finally returns to CIO with the operation status in register Y.

The IOCB need not be opened nor closed in order for you to request CIO to perform a GET STATUS operation; the handler must check where there are restrictions. See Section 5 for a discussion of the CIO actions involved with a GET STATUS operation using both open and closed IOCB's, and note the impact of this operation on the use of the buffer address parameter.

## SPECIAL

This handler entry is used to support all functions not handled by the other entry points, such as diskette file RENAME, display DRAW, etc. Specifically, if the IOCB command byte value is greater than \$0D, then CIO will use the SPECIAL entry point. The handler must interrogate the command byte to determine if the requested operation is supported.

At handler entry, the following parameters can be of interest:

X = index to originating IOCB.  
Y = \$92 (status = function not implemented by handler).

ICDNOZ [0021] = device number (1-4, for multiple device handlers).  
ICCOMZ [0022] = command byte.  
ICBALZ/ICBALH [0024/0025] = buffer address.  
ICBLLZ/ICBLHZ [0028/0029] = buffer length.  
ICAX1Z/ICAX2Z [002A/002B] = device-specific information.

The handler will perform the indicated operation, if possible, and return to CIO with the operation status in register Y.

The IOCB need not be opened nor closed in order for you to request CIO to perform a SPECIAL operation; the handler must check where there are restrictions. See Section 5 for a discussion of the CIO actions involved with a SPECIAL operation using both open and closed IOCB's, and note the impact of this on the use of the buffer address parameter.

## Error Handling

Error handling has been simplified somewhat by having CIO handle outer level errors and having SIO handle Serial bus errors, leaving the handler to process the remaining errors. These errors include:

- out-of-range parameters.
- [BREAK] key abort.
- Invalid command.
- Read after end of file.

The current handlers respond to errors using the following guidelines:

- They keep the recovery simple (and therefore predictable and repeatable).

- They Do not interact directly with you for recovery instructions.

- They lose as little data as possible.

- They make all attempts to maintain the integrity of file oriented device storage -- this involves the initial design of the structural elements as well as error recovery techniques.

## Resource Allocation

Nonresident handlers needing code and/or data space in RAM should use the techniques listed below, to assure nonconflict with other parts of the OS, including other nonresident handlers.

## Zero-Page RAM

Zero-page RAM has no spare bytes, and even if there were, there is no allocation scheme to support multiple program assignment of the spares. Therefore, the nonresident handler must save and restore the bytes of zero-page RAM it is going to use. The bytes to use must be chosen carefully, according to the following criteria:

The bytes cannot be accessed by an interrupt routine.

The bytes cannot be accessed by any noninterrupt code between the time the handler modifies the bytes and then restores the original values.

A simple save/restore technique would utilize the stack in a manner similar to that shown below:

```
LDA COLCRS ; (for example)
PHA ; SAVE ON STACK.
LDA COLCRS+1
PHA

LDA HPOINT ; HANDLER'S POINTER.
STA COLCRS
LDA HPOINT+1
STA COLCRS+1

XXX (COLCRS),Y ; DO YOUR POINTER THING.

PLA ; RESTORE OLD DATA.
STA COLCRS+1
PLA
STA COLCRS
```

Note that the Display Handler or Screen Editor should not be called before restoring the original value of COLCRS, because COLCRS is a variable used by those routines.

## Nonzero-Page RAM

There is no allocation scheme to support the assignment of fixed regions of nonzero-page RAM to any specific process, so the handler has three choices:

1. Make a dynamic allocation at initialization time by altering MEMLO [02E7].
2. Include the variables with the handler for RAM-resident handlers. This still involves altering MEMLO at the time the handler is booted.
3. If the handler replaces one of the resident handlers (by removing the resident handler's entry in the device table), then the new handler can use any RAM that the

formerly resident handler would have used.

### Stack Space

In most cases, there are no restrictions on the use of the stack by a handler. However, if the handler plans to push more than a couple dozen bytes to the stack; then it should do a stack overflow test, and always leave stack space for interrupt processing.

### HANDLER/SIO INTERFACE

This section describes the interface between serial bus device handlers and the serial bus I/O utility (SIO). SIO completely handles all bus transactions following the device-independent bus protocol. SIO is responsible for the following functions:

- Bus data format and timing from computer end.

- Error detection, retries and statuses.

- Bus timeout.

- Transfer of data between the bus and the caller's buffer.

### Calling Mechanism

SIO has a single entry point SIOV [E459] for all operations. The device control block (DCB) [0300] contains all parameters passed to SIO. The DCB contains the following bytes:

DEVICE BUS ID -- DDEVIC [0300]

The bus ID of the device is set by the handler prior to calling SIO (see Appendix I).

DEVICE UNIT # -- DUNIT [0301]

This byte indicates that of n units of a given device type to access, and is set by the handler prior to calling SIO. This value usually comes from ICDNOZ. SIO accesses the bus device whose address is equal to the value of DDEVIC plus DUNIT minus 1 (the lowest unit number is normally equal to 1).

DEVICE COMMAND -- DCOMND [0302]

The handler sets this byte prior to calling SIO. It will be sent to the bus device as part of the command frame. See Appendix I for device command byte values.

## DEVICE STATUS -- DSTATS [0303]

This byte is bidirectional. The handler will use DSTATS to indicate to SIO what to do after the command frame is sent and acknowledged. SIO will use it to indicate to the handler the status of the requested operation.

Prior to an SIO call:

```

 7 0
+---+---+---+---+---+
!W!R! unused !
+---+---+---+---+---+
```

Where: W,R = 0,0 indicates no data transfer is associated with the operation.

0,1 indicates a data frame is expected from the device.

1,0 indicates a data frame is to be sent to the device.

1,1 is invalid.

After an SIO call:

```

 7 0
+---+---+---+---+---+
! status code !
+---+---+---+---+---+
```

See Appendix C for the possible SIO operation status codes.

## HANDLER BUFFER ADDRESS -- DBUFLO/DBUFHI [0304/0305]

The handler sets this 2-byte pointer. It indicates the source or destination buffer for device data or status information.

## DEVICE TIMEOUT -- DTIMLO [0306]

The handler sets this byte. It specifies the device timeout time in units of 64/60 of a second. For example, a count of 6 specifies a timeout of 6.4 seconds.

## BUFFER LENGTH/BYTE COUNT -- DBYTLO/DBYTHI [0308/0309]

The handler sets this 2-byte count for the current operation, and indicates the number of data bytes to be transferred into or out of the buffer. This parameter is not required if the STATUS byte W and R bits are both zero. These values indicate that no data transfer is to take place.

**WARNING:** There is a bug in SIO that causes incorrect actions when the last byte of a buffer is in a memory address ending in \$FF, such as 13FF, 42FF, etc.

## AUXILIARY INFORMATION -- DAUX1/DAUX2 [030A/030B]

The handler sets these 2-bytes. The SIO includes them in the bus command frame; they have device-specific meanings.

### Functions Supported

SIO does not examine the COMMAND byte it sends to the device, because all bus transactions are expected to conform to a universal protocol. The protocol includes three forms, stated below (as seen from the computer):

- Send command frame.

- Send command frame and send data frame.

- Send command frame and receive data frame.

The values of the W and R bits in the status byte select the command form.

### Error Handling

SIO handles most of the serial bus errors for the handler, as indicated below:

Bus timeout -- SIO provides a uniform command frame and data frame ACK byte timeout of 1/60 of a second - 0 / + 1/60. The handler specifies the maximum COMPLETE byte timeout value in DTIMLO.

Bus errors -- SIO detects and reports UART overrun and framing errors. The sensing of these errors in any received byte will cause the entire associated frame to be considered bad.

Data frame checksum error -- SIO validates the checksum on all received data frames and generates a checksum for all transmitted frames.

Invalid response from device -- In addition to the error conditions stated above, SIO checks that the ACK and COMPLETE responses are proper (ACK = \$41 and COMPLETE = \$43). ACK stands for acknowledge.

Bus operation retries -- SIO will attempt one complete command retry if the first attempt is not error free, where a complete command try consists of up to 14 attempts to send (and acknowledge) a command frame, followed by a single attempt to

receive the COMPLETE code and possibly a data frame.

NOTE: There is a bug in the retry logic for data writes, such that if the command frame is acknowledged by the controller, but the data frame is not acknowledged, then SIO will retry indefinitely.

Unified error status codes -- SIO provides device-independent error codes (see Appendix C).

## SERIAL I/O BUS CHARACTERISTICS AND PROTOCOL

This section describes:

- o The electrical characteristics of the ATARI 400 and ATARI 800 Home Computers serial bus
- o The use of the bus to send bytes of data,
- o The organization of the bytes as "frames" (records),
- o The overall command sequences that utilize frames and response bytes to provide computer/peripheral communication.

### Hardware/Electrical Characteristics

The ATARI 400 and the ATARI 800 Home Computers communicate with peripheral devices over a 19,200 baud asynchronous serial port. The serial port consists of a serial DATA OUT (transmission) line, a serial DATA IN (receiver) line and other miscellaneous control lines.

Data is transmitted and received as 8 bits of serial data (LSB sent first) preceded by a logic zero start bit and succeeded by a logic one stop bit. The serial DATA OUT is transmitted as positive logic (+4v = one/true/high, 0v = zero/false/low). The serial DATA OUT line always assumes its new state when the serial CLOCK OUT line goes high; CLOCK OUT then goes low in the center of the DATA OUT bit time.

An end view of the Serial bus connector at the computer or peripheral is shown below (the cable connectors would of course be a mirror image):

|   |   |   |   |    |    |    |
|---|---|---|---|----|----|----|
| 2 | 4 | 6 | 8 | 10 | 12 |    |
| 0 | 0 | 0 | 0 | 0  | 0  |    |
| 0 | 0 | 0 | 0 | 0  | 0  | 0  |
| 1 | 3 | 5 | 7 | 9  | 11 | 13 |

where: 1 = computer CLOCK IN.  
 2 = computer CLOCK OUT.  
 3 = computer DATA IN.  
 4 = GND.  
 5 = computer DATA OUT.  
 6 = GND.  
 7 = COMMAND-.  
 8 = MOTOR CONTROL.  
 9 = PROCEED-.  
 10 = +5v/READY.  
 11 = computer AUDIO IN.  
 12 = +12v.  
 13 = INTERRUPT-.

Figure 9-4 Serial Bus Connector Pin Descriptions

CLOCK IN is not used by the present OS and peripherals. This line can be used in future synchronous communications schemes.

CLOCK OUT is the serial bus clock. CLOCK OUT goes high at the start of each DATA OUT bit and returns to low in the middle of each bit.

DATA IN is the serial bus data line to the computer.

Pin 4 GND is the signal/shield ground line.

DATA OUT is the serial bus data line from the computer.

Pin 6 GND is the signal/shield ground line.

COMMAND- is normally high and goes low when a command frame is being sent from the computer.

MOTOR CONTROL is the cassette motor control line (high=on, low= off).

PROCEED- is not used by the present OS and peripherals; this line is pulled high.

+5v/READY indicates that the computer is turned on and ready. This line can also be used as a +5 volt supply of 50ma current rating for ATARI peripherals only.

AUDIO IN accepts an audio signal from the cassette.

+12V is a +12 volt supply of unknown current rating for ATARI peripherals only.

INTERRUPT- is not used by the present OS and peripherals; this line is pulled high.

There are no pin reassignments made in the Serial bus cable, so pin 3, the computer's DATA IN line, is the peripheral's data output line; and similarly for pin 5.

### Serial Port Electrical Specifications

#### Peripheral input:

$V_{IH} = 2.0v$  min.

$V_{IL} = 0.4v$  max.

$I_{IH} = 20\mu a$ . max. @  $V_{IH} = 2.0v$

$I_{IL} = 5\mu a$ . max. @  $V_{IL} = .4v$

#### Peripheral output (open collector bipolar):

$V_{OL} = 0.4v$  max. @ 1.6 ma.

$V_{OH} = 4.5v$  min. with external 100Kohm pull-up.

#### $V_{CC}/READY$ input:

$V_{IH} = 2.0v$  min. @  $I_{IH} = 1ma$ . max.

$V_{IL} = 0.4v$  max.

Input goes to logic zero when open.

### Bus Commands

The bus protocol specifies that all commands must originate from the computer, and that peripherals will present data on the bus only when commanded to. Every bus operation will go to completion before another bus operation is initiated (no overlap). An error detected at any point in the command sequence will abort the entire sequence.

A bus operation consists of the following elements:

Command frame from the computer.

Acknowledgement (ACK) from the peripheral.

Optional data frame to or from the computer.

Operation complete (COMPLETE) from the peripheral.

## Command Frame

The serial bus protocol provides for three types of commands: 1) data send, 2) data receive and 3) immediate (no data -- command only). There is a common element in all three types, a command frame consisting of five bytes of information sent from the computer while the COMMAND- line is held low. The format of the command frame is shown below:

```
+-----+
| device ID |
+-----+
| command |
+-----+
| auxiliary #1 |
+-----+
| auxiliary #2 |
+-----+
| checksum |
+-----+
```

Figure 9-5 Serial Bus Command Frame Format

The device ID specifies that of the serial bus devices is being addressed (see Appendix I for a list of device IDs).

The command byte contains a device-dependent command (see Appendix I for a list of device commands).

The auxiliary bytes contain more device-dependent information.

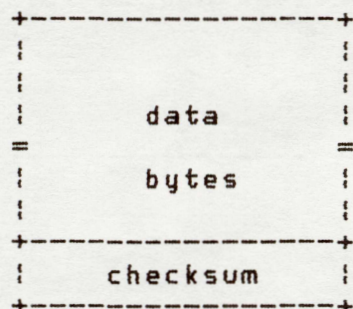
The checksum byte contains the arithmetic sum of the first four bytes (with the carry added back after every addition).

## Command Frame Acknowledge

The peripheral being addressed would normally respond to a command frame by sending an ACK byte (\$41) to the computer; if there is a problem with the command frame, the peripheral should not respond.

## Data Frame

Following the command frame (and ACK) can be an optional data frame that is formatted as shown below:



This data frame can originate at the computer or at the device controller, depending upon the command. Current device controllers expect fixed-length data frames as does the computer, where the data frame length is a fixed function of the device type and command.

The checksum value in the data frame is the arithmetic sum of all of the frame data preceding the checksum, with the carry from each addition being added back (the same as for the command frame).

In the case of the computer sending a data frame to a peripheral, the peripheral is expected to send an ACK if the data frame is acceptable, and send a NAK (\$4E), or do nothing if the data frame is unacceptable. See the first flowchart in Section 9.

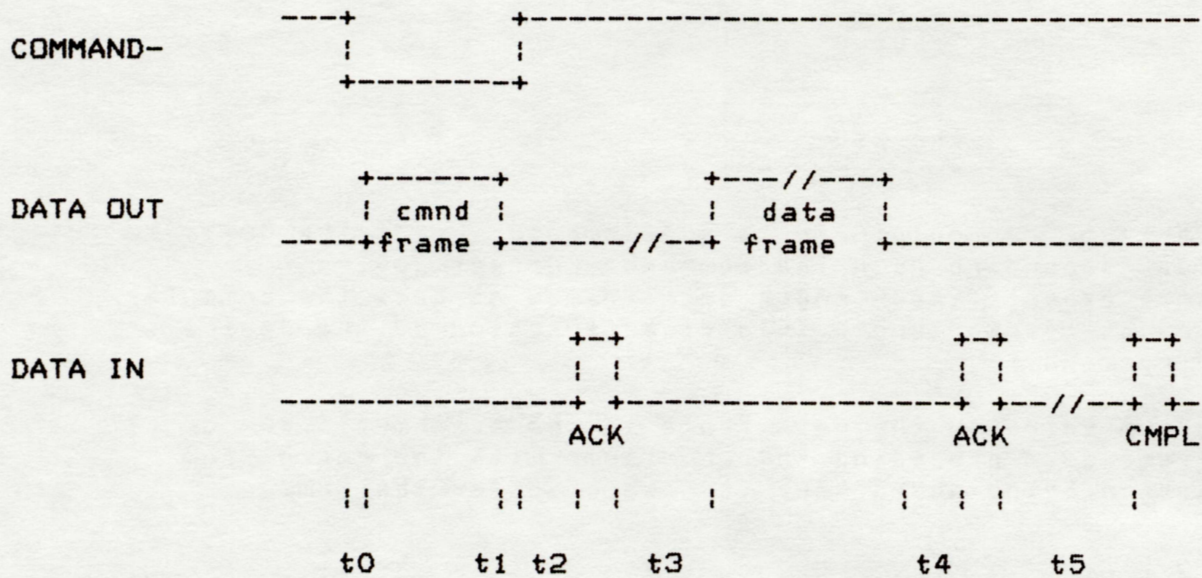
#### Operation Complete

A peripheral is also expected to send an operation-COMplete byte (\$43) at the time the commanded operation is complete. The location of this byte in the command sequence for each command type is shown in the timing diagrams in Section 9. If the operation cannot go to normal, error-free completion, the peripheral should respond with an ERROR byte (\$45) instead of COMPLETE.

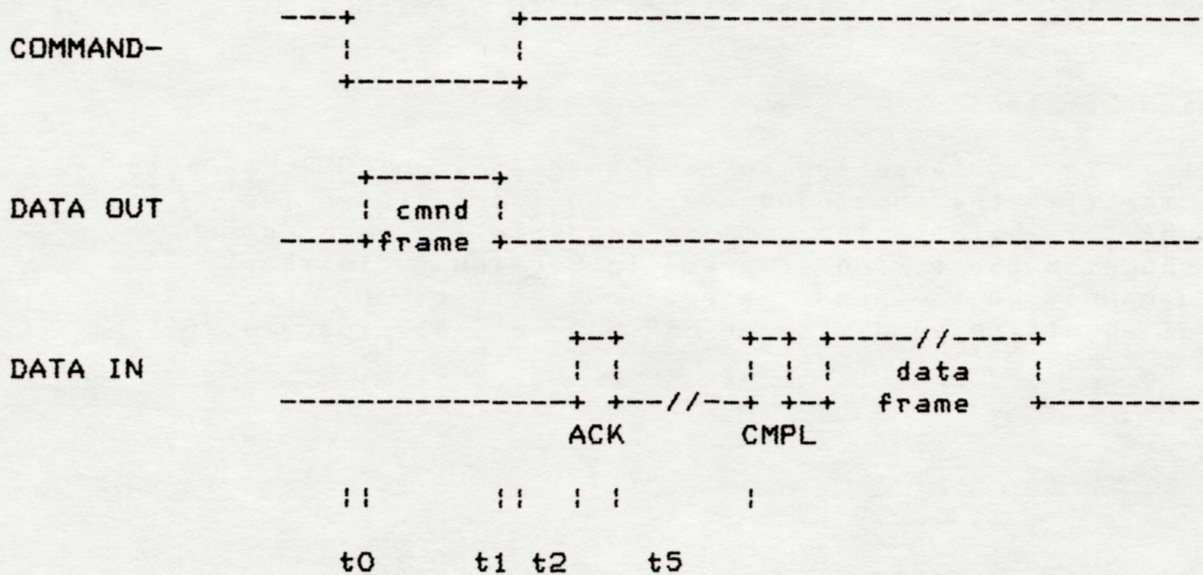
## Bus Timing

This section provides timing diagrams for the three types of command sequences: data send, data receive, and immediate.

### DATA SEND sequence:



### DATA RECEIVE sequence:



IMMEDIATE sequence:

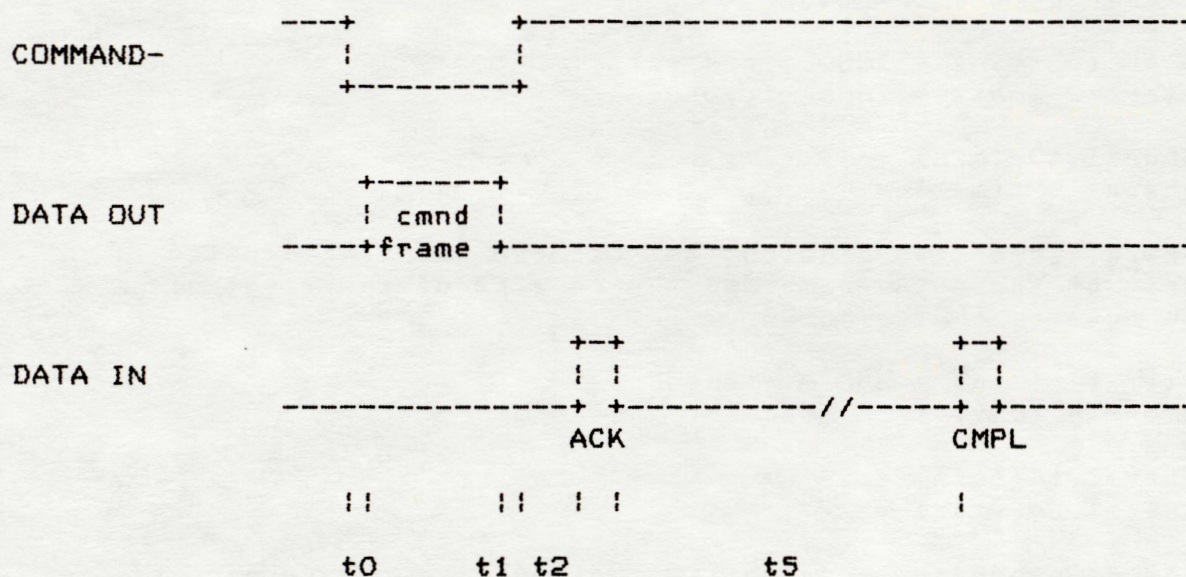


Figure 9-6 Serial Bus Timing Diagram

The computer generates a delay ( $t_0$ ) between the lowering of COMMAND- and the transmission of the first byte of the command frame.

computer  $t_0$  (min) = 750 microsec.  
computer  $t_0$  (max) = 1600 microsec.

peripheral  $t_0$  (min) = ??  
peripheral  $t_0$  (max) = ??

The computer generates a delay ( $t_1$ ) between the transmission of the last bit of the command frame and the raising of the COMMAND- line.

computer  $t_1$  (min) = 650 microsec.  
computer  $t_1$  (max) = 950 microsec.

peripheral  $t_1$  (min) = ??  
peripheral  $t_1$  (max) = ??

The peripheral generates a delay ( $t_2$ ) between the raising of COMMAND- and the transmission of the ACK byte by the peripheral.

computer  $t_2$  (min) = 0 microsec.  
computer  $t_2$  (max) = 16 msec.

peripheral  $t_2$  (min) = ??  
peripheral  $t_2$  (max) = ??

The computer generates a delay (t3) between the receipt of the last bit of the ACK byte and the transmission of the first bit of the data frame by the computer.

computer t3 (min) = 1000 microsec.  
computer t3 (max) = 1800 microsec.

peripheral t3 (min) = ??  
peripheral t3 (max) = ??

The peripheral generates a delay (t4) between the transmission of the last bit of the data frame and the receipt of the first bit of the ACK byte by the computer.

computer t4 (min) = 850 microsec.  
computer t4 (max) = 16 msec.

peripheral t4 (min) = ??  
peripheral t4 (max) = ??

The Peripheral generates a delay (t5) between the the receipt of the last bit of the ACK byte and the first bit of the COMPLETE byte by the computer.

computer t5 (min) = 250 microsec.  
computer t5 (max) = 255 sec. (handler-dependent)

peripheral t5 (min) = ??  
peripheral t5 (max) = N/A

## HANDLER ENVIRONMENT

Nonresident handlers can be installed in at least three different manners:

1. As booted software from diskette or cassette.
2. Resident in a cartridge (A or B).
3. Downloaded from a serial bus device.

This section will discuss the basic mechanisms for handler installation for these environments. In order to fully utilize the information in this section, you must have read and understood the following sections:

|                                          |            |
|------------------------------------------|------------|
| Program environments . . . . .           | Section 3  |
| RAM region . . . . .                     | Section 4  |
| Memory dynamics. . . . .                 | Section 4  |
| System initialization. . . . .           | Section 7  |
| Adding new device handlers/peripherals . | Section 9  |
| Program environment and initialization . | Section 10 |

## Bootable Handler

The diskette- or cassette-booted software will insert the handler's vector table pointer and name to the device table whenever the booted software's initialization entry point is entered (on power-up and system reset). Remember that both power-up and system reset clear the device table of all but the resident handler entries.

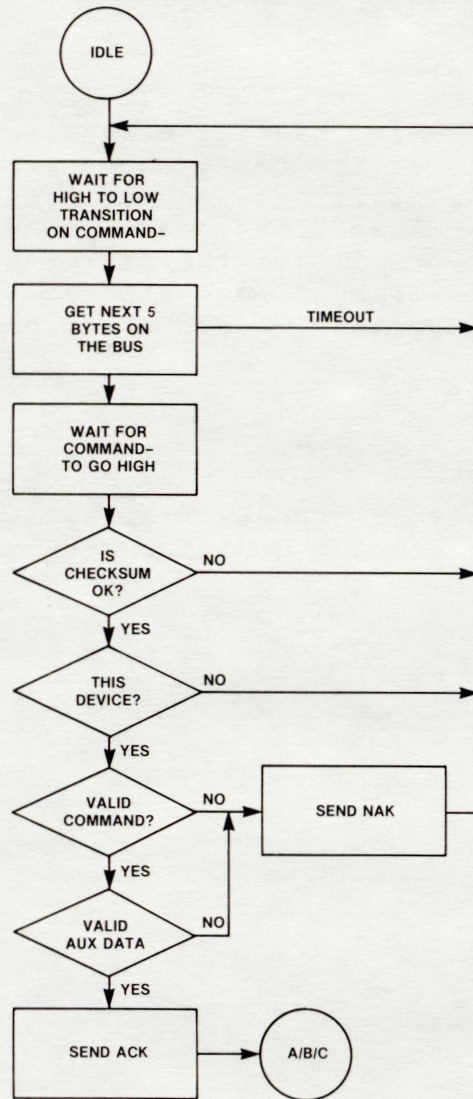
## Cartridge Resident Handler

The cartridge software will insert the handler's vector table pointer and name to the device table whenever the cartridge's initialization entry point is entered (on power-up and system reset). Remember that both power-up and system reset clear the device table of all but the resident handler entries; therefore the device table must be reestablished by the handler-initialization procedure upon every entry.

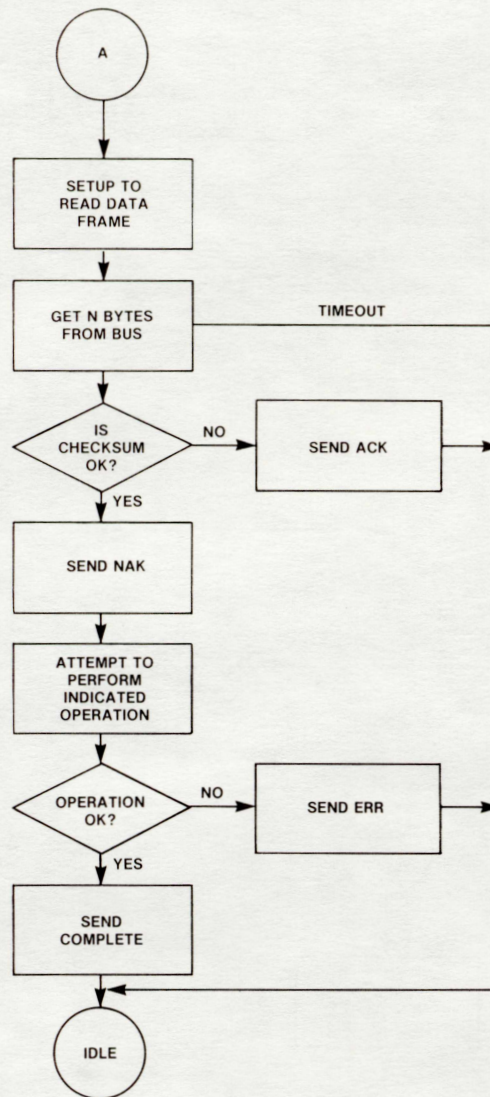
## FLOWCHARTS

The following pages contain process flowcharts showing the SIO and peripheral actions for the Serial bus command forms.

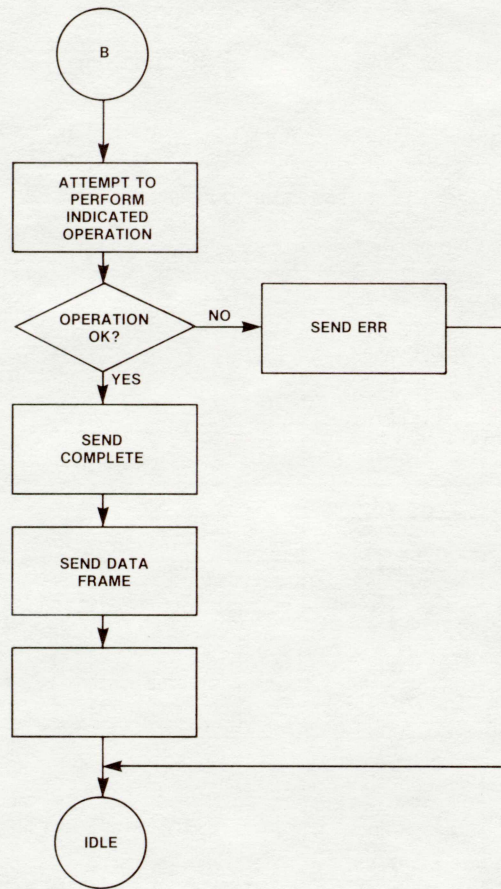
# PERIPHERAL'S COMMAND FRAME PROCESSING



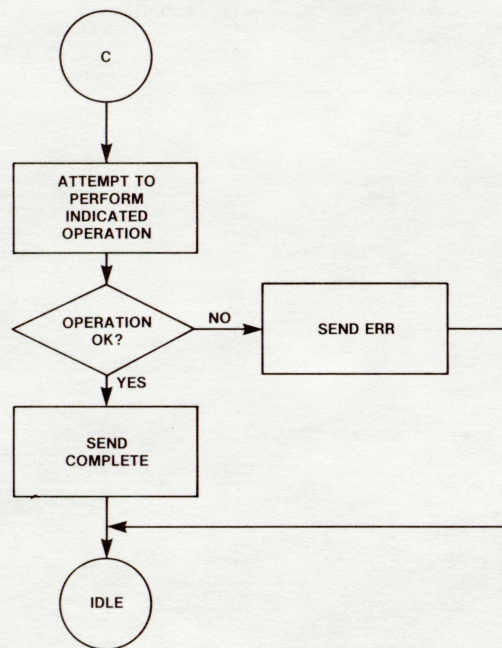
DATA FRAME TO PERIPHERAL



# DATA FRAME TO COMPUTER



# IMMEDIATE



## 10 PROGRAM ENVIRONMENT AND INITIALIZATION

This section discusses possible alternative software environments using OS Configurations. Environments other than those discussed here are also possible. A thorough understanding of the power-up and system reset processes (see Section 7) will be necessary to evaluate all alternative environments.

### CARTRIDGE

Most games (and some language processors) are supported via the cartridge environment. The cartridge resident software is in control of the system, sometimes using the OS and sometimes not. A cartridge can specify whether the diskette is to be booted at power-up time, whether the cartridge is to provide the controlling software, or whether the cartridge is a special diagnostic cartridge. These options are specified by bits in the cartridge header, as shown below:

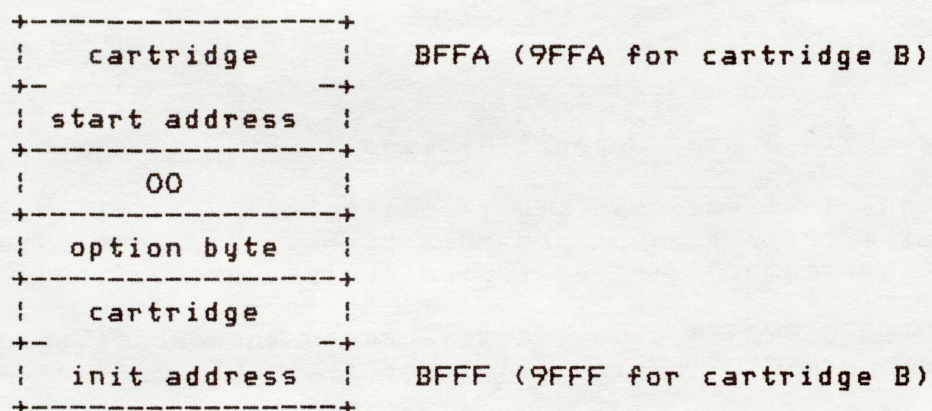


Figure 10-1 Cartridge Header Format

The byte of "00" is used to allow the OS to determine when a cartridge is inserted; locations BFFC and 9FFC will not read zero when there is neither RAM at those locations nor a cartridge inserted. RAM is differentiated from a cartridge by its ability to be altered.

The option byte has the following option bits:

bit 0 = 0, then do not boot the diskette.  
1, then boot the diskette.

Bit 2 = 0, then init but do not start the cartridge.  
1, then init and start the cartridge.

bit 7 = 0, then cartridge is not a diagnostic cartridge.  
1, then cartridge is a diagnostic cartridge and control  
will be given to the cartridge before any of the OS  
is initialized (JMP (BFFE)).

The cartridge init address specifies the location to which the OS will  
JSR during all power-up and system reset operations. As a minimum,  
this vector should point to an RTS instruction.

The cartridge start address specifies the location to which the OS  
will JMP during all power-up and system reset operations, if  
bit 1 of the option byte is = 1. The application should examine  
the variable WARMST [0008] if system reset action is to be  
different than power-up (WARMST will be zero on power-up and  
nonzero thereafter).

#### Cartridge Without Booted Support Package

A cartridge that does not specify the diskette-boot option and does  
not support the cassette-boot possibility can use lower memory  
(from 0480 to the address in MEMTOP [02E5]) in any way it sees  
fit.

#### Cartridge With Booted Support Package

A cartridge that does specify the diskette-boot option or does  
support the cassette-boot possibility must use some care in its  
use of lower memory. The following regions are defined:

0480-06FF is always available to the cartridge.  
MEMLO/MEMTOP region is always available to the cartridge.

#### DISKETTE-BOOTED SOFTWARE

Software can be booted from the disk drive at power-up time in  
response to one of the following conditions:

Neither Cartridge A nor B is inserted.

Cartridge A is inserted and has bit 0 of its option byte [BFFD] = 1.

Cartridge B is inserted and has bit 0 of its option byte [9FFD] = 1.

If any of these conditions are met, the OS will attempt to read the boot record from sector #1 of disk drive 1 and then transfer control to the software that was read in. The exact sequence of operations will be explained later in this section.

#### Diskette-Boot File Format

The key region of a diskette-boot file is the first six bytes, which are formatted as shown below:

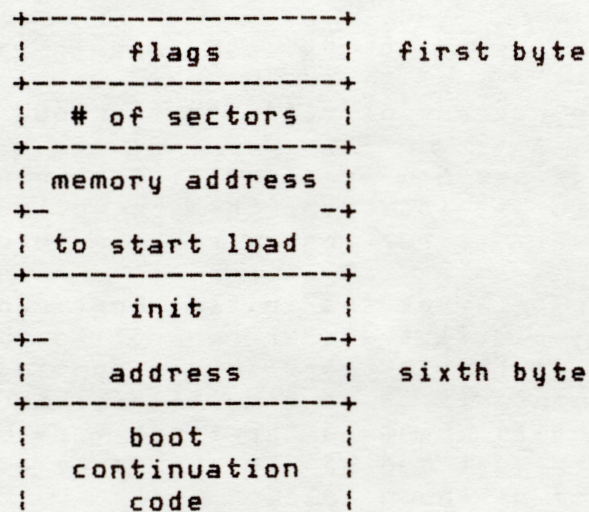


Figure 10-2 Diskette-Boot File Format

The first byte is stored in DFLAGS [0240], but is otherwise unused. It should equal zero.

The second byte contains the number of 128-byte diskette sectors to be read as part of the boot process (including the record containing this information). This number can range from 1 to 255, with 0 meaning 256.

The third and fourth bytes contain the address (lo,hi) at which to start loading the first byte of the file.

The fifth and sixth bytes contain the address (lo,hi) to which the booter will transfer control after the boot process is complete and whenever the [SYSTEM.RESET] key is pressed.

The Diskette File Management System (FMS) has extra bytes assigned to its boot record, but this is a special case of the generalized diskette-boot and is discussed in Section 5.

#### Diskette-Boot Process

If no cartridge is installed, then the diskette will follow these steps to boot up:

1. Read the first diskette record to the cassette buffer [0400].
2. Extract information from the first six bytes:

Save the flags byte to DFLAGS [0240,1]. Save the # of sectors to boot to DBSECT [0241,1]. Save the load address to BOOTAD [0242,2]. Save the initialization address in DOSINI [000C,2].

3. Move the record just read to the load address specified.
4. Read the remaining records directly to the load area.
5. JSR to the load address+6 where a multistage boot process can continue. The carry bit indicates the success of this operation (carry set = error, carry reset = success).

NOTE: During step 5, after the initial boot process is complete, the booter will transfer control to the seventh byte of the first record. The software should continue the boot process at this point, if it is a multistage boot. The value of MEMLO [02E7] should point to the first free RAM location beyond the software just booted. It should be established by the booted software as shown below:

```
LDA #END+1 ; SET UP LSB.
STA MEMLO
STA APPMHI
LDA #END+1/256 ; SET UP MSB.
STA MEMLO+1
STA APPMHI+1
```

If the booted software is to take control of the system at the end of the boot operation, the vector DOSVEC [000A] must be set up by the application at this time; DOSVEC points to the

restart entry for the booted application. If the booted software is not to take control, then DOSVEC should remain unchanged.

```
LDA #RESTRT ; RESTART LSB.
STA DOSVEC
LDA #RESTRT/256
STA DOSVEC+1
```

6. JSR indirectly through DOSINI for initialization of the application; the application will initialize and return.

NOTE: The OS enters the initialization point on every system reset and power-up. Internal initialization can take place during system reset and power-up as well. Initialization can also be deferred until Step 7 for controlling applications.

7. JMP indirectly through DOSVEC to transfer control to the application.

NOTE: Pressing the [SYSTEM.RESET] key after the application is fully booted will cause steps 6 and 7 to be repeated.

#### Sample Diskette-Bootable Program Listing

This skeletal program can be booted from the diskette. It retains control when it is entered.

; THIS IS THE START OF THE PROGRAM FILE.

```
PST= $0700 ; (OR SOME OTHER LOCATION).
*= PST ; (.ORG).
```

; THIS IS THE diskette-boot CONTROL INFORMATION.

```
.BYTE 0 ;
.BYTE PND-PST+127/128 ; NUMBER OF RECORDS.
.WORD PST ; MEMORY ADDRESS TO START LOAD.
.WORD PINIT ; PROGRAM INIT.
```

```

; THIS IS THE START OF THE BOOT CONTINUATION.

 LDA #PND ; ESTABLISH LOW MEMORY LIMITS.
 STA MEMLO
 STA APPMHI
 LDA #PND/256
 STA MEMLO+1
 STA APPMHI+1

 LDA #RESTRT ; ESTABLISH RESTART VECTOR.
 STA DOSVEC
 LDA #RESTRT/256
 STA DOSVEC+1

 CLC ; SET FLAG FOR SUCCESSFUL BOOT.
 RTS

; APPLICATION INITIALIZATION ENTRY POINT.

PINIT RTS ; NOTHING TO DO HERE FOR ...
 ; ... CONTROLLING APPLICATION.

; THE MAIN BODY OF THE PROGRAM FOLLOWS.

RESTRT=*

; THE MAIN BODY OF THE PROGRAM ENDS HERE.

PND= * ; 'PND' = NEXT FREE LOCATION.
 .END

```

Figure 10-3 Diskette-Bootable Program Listing Example

#### Program to Create Diskette-Boot Files

This section provides a program that can be used to make bootable files on diskettes. The program given is not the only one possible, and no claims are made as to its elegance.

Shown below is a listing of the program to create diskette-boot files.

```
; THIS PROGRAM WRITES A SINGLE "FILE" TO THE DISKETTE AND IS
; USED IN CONJUNCTION WITH A PROCEDURE TO MAKE DISKETTE-
; BOOTABLE FILES. THE FOLLOWING TWO SYMBOLS MUST BE EQUATED
; USING THE MEMORY LIMITS OF THE PROGRAM TO BE COPIED:
```

```
;
; 'PST' = PROGRAM START ADDRESS (SEE SAMPLE PROGRAM).
; 'PND' = PROGRAM END ADDRESS (SEE SAMPLE PROGRAM).
```

```
SECSIZ=128 ; DISKETTE SECTOR SIZE.
PST= $0700
PND= $1324
FLEN= PND-PST+SECSIZ-1/SECSIZ ; # OF SECTORS IN FILE.

*= $B000 ; THIS PROGRAM'S ORIGIN.
```

```
BOOTB BRK ; *** LOAD APPLICATION ***
```

```
; SET UP DEVICE CONTROL BLOCK FOR DISKETTE HANDLER CALL
```

```
 LDA #FLEN ; # OF SECTORS TO WRITE.
 STA COUNT

 LDA #1 ; DISK DRIVE #1.
 STA DUNIT

 LDA #'W ; SET UP FOR WRITE WITH CHECK.
 STA DCOMND

 LDA #PST ; POINT TO START OF APPLIC. PROG.
 STA DBUFLO
 LDA #PST/256
 STA DBUFHI

 LDA #01 ; SET UP STARTING SECTOR # = 0001.
 STA DAUX1
 LDA #00
 STA DAUX2
```

; NOW WRITE THE FILE ONE SECTOR AT A TIME.

```
BOT010 JSR DSKINV ; WRITE ONE SECTOR.
 BMI DERR ; ERROR.

 LDA DBUFLO ; INCREMENT MEMORY ADDRESS.
 CLC
 ADC #SECSIZ
 STA DBUFLO
 LDA DBUFHI
 ADC #0
 STA DBUFHI

 INC DAUX1 ; INCREMENT SECTOR #.
 BNE BOT020
 INC DAUX2

BOT020 DEC COUNT ; MORE SECTORS TO WRITE?
 BNE BOT010 ; YES.

 BRK ; STOP WHEN DONE.

DERR BRK ; STOP ON ERROR.

COUNT **++1 ; SECTOR COUNT.

; THIS IS THE CARTRIDGE HEADER

** $BFF9 ; "A" CARTRIDGE.

INIT RTS
 .WORD BOOTB
 .BYTE 0,4
 .WORD INIT

 .END
```

#### CASSETTE-BOOTED SOFTWARE

You can boot software from the cassette as well as from the diskette, at power-up. The following requirements must be met in order to boot from the cassette:

- o You must be pressing the [START] key as power is applied to the system.
- o A cassette tape with a proper boot format file must be installed in the cassette drive, and the PLAY button must be pressed.

- o When you are given the audio prompt by the cassette handler you must press the [RETURN] key.

If all of these conditions are met, the OS will read the boot file from the cassette and then transfer control to the software that was read in. The exact sequence of operations will be explained later in this section.

### Cassette-Boot File Format

The key region of a cassette-boot file is the first six bytes, that are formatted as shown below:

```
+-----+
| |
+-----+
| # of Records |
+-----+
| Memory Address |
+---+---+
| To Start Load |
+-----+
| Init |
+---+---+
| address |
+-----+
```

The first byte is not used by the cassette-boot process.

The second byte contains the number of 128-byte cassette records to be read as part of the boot process (including the record containing this information). This number can range from 1 to 255, with 0 meaning 256.

The third and fourth bytes contain the address (lo,hi) to which the booter will transfer control after the boot process is complete and whenever the [SYSTEM.RESET] key is pressed.

### Cassette-Boot Process

The cassette-boot process is described step-by-step for a configuration in that no cartridge is installed and no diskettes are attached. For the general case see Section 7.

1. Read the first cassette record to the cassette buffer.
2. Extract information from the first six bytes:

Save the # of records to boot. Save the load address. Save the initialization address in CASINI [0002]

3. Move the record just read to the load address specified.
4. Read the remaining records directly to the load area.
5. JSR to the load address+6 where a multistage boot process can continue; the carry bit will indicate the success of this operation (carry set=error, carry reset=success).
6. JSR indirectly through CASINI for initialization of the application; the application will initialize and return.
7. JMP indirectly through DOSVEC to transfer control to the application.

Pressing the [SYSTEM.RESET] key after the application is fully booted will cause steps 6 and 7 to be repeated.

NOTE: After the initial boot process is complete, the booter will transfer control to the seventh byte of the first record; at this point the software should continue the boot process (if it is a multistage boot) and then stop the cassette drive, which due to a system bug will still be running, using the following instruction sequence:

```
LDA #$3C
STA PACTL [D302]
```

The application should then set a value in MEMLO [0237] that points to the first free RAM location beyond the software just booted, as shown below:

```
LDA #END+1
STA MEMLO
STA APPMHI
LDA #END+1/256
STA MEMLO+1
STA APPMHI+1
```

If the booted software is to take control of the system at the end of the boot operation, the vector DOSVEC [000A] must be set up by the application at this time; DOSVEC points to the restart entry for the booted application. If the booted software is not to take control, then DOSVEC should remain unchanged.

```
LDA #RESTRT ; RESTART LSB
STA DOSVEC
LDA #RESTRT/256
STA DOSVEC+1
```

NOTE: The initialization point is entered on every system reset and power-up; internal initialization can take place here.

For controlling applications initialization can also be deferred until step 7.

### Sample Cassette-Bootable Program Listing

Shown below is a skeletal program that can be booted from the cassette and that retains control when it is entered.

; THIS IS THE START OF THE PROGRAM FILE.

```
PST= $0700 ; (OR SOME OTHER LOCATION).
*= PST ; (.ORG).
```

; THIS IS THE cassette-boot CONTROL INFORMATION.

```
.BYTE 0 ; (DOESN'T MATTER).
.BYTE PND-PST+127/128 ; NUMBER OF RECORDS.
.WORD PST ; MEMORY ADDRESS TO START LOAD.
.WORD PINIT ; PROGRAM INIT.
```

; THIS IS THE START OF THE BOOT CONTINUATION.

```
LDA $$3C ; STOP THE CASSETTE.
STA PACTL

LDA #PND ; ESTABLISH LOW MEMORY LIMITS.
STA MEMLO
STA APPMHI
LDA #PND/256
STA MEMLO+1
STA APPMHI+1

LDA #RESTRT ; ESTABLISH RESTART VECTOR.
STA DOSVEC
LDA #RESTRT/256
STA DOSVEC+1

CLC ; SET FLAG FOR SUCCESSFUL BOOT.
RTS
```

; APPLICATION INITIALIZATION ENTRY POINT.

```
PINIT RTS ; NOTHING TO DO HERE FOR ...
 ; ... CONTROLLING APPLICATION.
```

; THE MAIN BODY OF THE PROGRAM FOLLOWS.

```
RESTRT=*
```

; THE MAIN BODY OF THE PROGRAM ENDS HERE.

```
PND= * ; 'PND' = NEXT FREE LOCATION.
 .END
```

Figure 10-4 Sample Cassette-Bootable Program

#### Program to Create Cassette-Boot Files

This section provides a program listing that can be used to make bootable files on cassette tapes. The program given is not the only one possible, and no claims are made as to its elegance.

Shown below is a listing of the program to create a cassette-boot file:

```
; THIS PROGRAM WRITES A SINGLE FILE TO THE CASSETTE AND IS
; USED IN CONJUNCTION WITH A PROCEDURE TO MAKE CASSETTE-
; BOOTABLE FILES. THE FOLLOWING TWO SYMBOLS MUST BE EQUATED
; USING THE MEMORY LIMITS OF THE PROGRAM TO BE COPIED:

; 'PST' = PROGRAM START ADDRESS (SEE SAMPLE PROGRAM).
; 'PND' = PROGRAM END ADDRESS (SEE SAMPLE PROGRAM).

PST= $0700
PND= $1324
FLEN= PND-PST+127/128*128 ; ROUND UP TO MULTIPLE OF 128.

*= $B000 ; THIS PROGRAM'S ORIGIN.

BOOTB LDX ##10 ; USE IOCB #1.

; FIRST OPEN THE CASSETTE FILE FOR WRITING.

 LDA #OPEN ; SET UP FOR DEVICE "OPEN."
 STA ICCOM, X

 LDA #OPNOT ; DIRECTION IS "OUTPUT."
 STA ICAX1, X
 LDA #$80 ; SELECT SHORT IRG.
 STA ICAX2, X

 LDA #CFILE ; SET UP POINTER TO DEVICE NAME.
 STA ICBAL, X
 LDA #CFILE/256
 STA ICBAH, X

 JSR CIOV ; ATTEMPT TO OPEN FILE.
 BMI CERR ; ERROR.

; NOW WRITE THE ENTIRE FILE AS ONE OPERATION.
```

```

LDA #PUTCHR ; SET UP FOR "PUT CHARACTERS. "
STA ICCOM, X

LDA #PST ; POINT TO START OF APPLIC. PROG.
STA ICBAL, X
LDA #PST/256
STA ICBAH, X

LDA #FLEN ; SET UP # OF BYTES TO WRITE.
STA ICBLL, X
LDA #FLEN/256
STA ICBLH, X

JSR CIOV ; WRITE ENTIRE FILE.
BMI CERR ; ERROR.

; NOW CLOSE THE FILE AFTER SUCCESSFUL WRITE.

LDA #CLOSE ; SET UP FOR "CLOSE. "
STA ICCOM, X

JSR CIOV ; CLOSE THE FILE.
BMI CERR ; ERROR.

BRK ; STOP WHEN DONE.

CERR BRK ; STOP ON ERROR.

CFILE .BYTE "C: ", CR ; FILE NAME.

; THIS IS THE CARTRIDGE HEADER

*= $BFF9 ; "A" CARTRIDGE.

INIT RTS
 .WORD BOOTB
 .BYTE 0, 4

 .WORD INIT
 .END

```

## 11 ADVANCED TECHNIQUES AND APPLICATION NOTES

This section presents information to use the capabilities of the OS and some of the hardware capabilities that aren't directly available through the OS, and in fact, can be in direct conflict with parts of the OS.

### SOUND GENERATION

The OS uses the POKEY sound generation capabilities only in the I/O subsystem, for cassette FSK tone generation, and for the "noisy bus" option in SIO.

#### Capabilities

The hardware provides four independently programmable audio channels that are mixed and sent to the television set as part of the composite video signal. The POKEY registers shown below are all concerned with sound control (as described in the ATARI Home Computer Hardware Manual).

|                               |                    |
|-------------------------------|--------------------|
| AUDCTL [D208]                 | Audio control.     |
| AUDC1 [D201] and AUDF1 [D200] | Channel 1 control. |
| AUDC2 [D203] and AUDF2 [D202] | Channel 2 control. |
| AUDC3 [D205] and AUDF3 [D204] | Channel 3 control. |
| AUDC4 [D207] and AUDF4 [D206] | Channel 4 control. |

#### Conflicts With OS

There are two potential conflicts with the OS involving sound generation:

- o The OS can generate its own sounds and then turn off all sounds as part of I/O operations to the cassette and the serial bus peripherals.
- o The OS does not turn off sounds when you press [SYSTEM.RESET] or [BREAK]. If the sounds are to be turned off under those conditions, the controlling program must provide that capability.

## SCREEN GRAPHICS

### Hardware Capabilities

The hardware capabilities for screen presentations are quite versatile; the OS uses a very small amount of the capability provided. The means of extension, however, are non-trivial; and making changes to a screen format while still utilizing the resident Display Handler will be difficult. See the ATARI Home Computer Hardware Manual for information regarding screen presentations.

### OS Capabilities

The resident Display Handler arbitrarily supports 8 of the 11 possible full screen modes (11 of 14 modes if the GTIA chip is used in place of the CTIA). The resident Display Handler allows for an optional "split-screen" text window of fixed size. The hardware allows for many more options than the Display Handler supports, as will be seen by reading the ATARI Home Computer Hardware Manual.

### Cursor Control

You can control the Display Handler text and graphics cursors directly (see Section 5 and Appendix L, B1-4).

### Color Control

You can alter the color register assignments that the Display Handler makes upon all OPEN commands (see Appendix L B7-8 and elsewhere). Note that every system reset or Display Handler OPEN will reset the values back to the system default.

## Alternate Character Sets

Two character sets are available in screen text modes 1 and 2. The value stored in the data base variable CHBAS [02F4] selects the character set of interest to you. The default value of \$E0 provides capital (uppercase) letters, numbers and the punctuation characters corresponding to display codes \$20 through \$5F in Appendix E). The alternate value of \$E2 provides lowercase letters and the special character graphics set (corresponding to display codes \$60 through \$7F and \$00 through \$1F in Appendix E).

User-defined character sets can also be obtained for text modes 0, 1, and 2 by providing the character matrix definitions in RAM and setting CHBAS to point to those definitions. CHBAS always contains the most significant bits of the memory address of the start of the character definitions, as shown below:

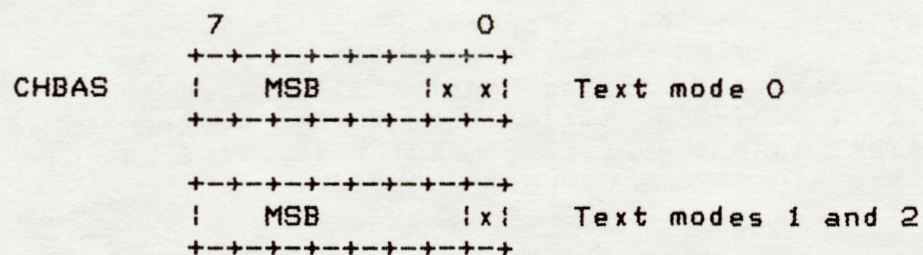


Figure 11-1 User-Defined Character Set Bit Memory Addresses

(X indicates an ignored address bit assumed to be 0.)

Each character is defined by an 8 x 8 bit matrix; the character '@' is defined as shown below:

|      |                     |  |   |
|------|---------------------|--|---|
|      | 7                   |  | 0 |
| Byte | +--+--+--+--+--+--+ |  |   |
|      | 0 0 0 0 0 0 0 0     |  | 0 |
|      | +--+--+--+--+--+--+ |  |   |
|      | 0 0 0 1 1 1 1 0 0   |  | 1 |
|      | +--+--+--+--+--+--+ |  |   |
|      | 0 1 1 1 0 1 1 0 0   |  | 2 |
|      | +--+--+--+--+--+--+ |  |   |
|      | 0 1 1 1 0 1 1 0 0   |  | 3 |
|      | +--+--+--+--+--+--+ |  |   |
|      | 0 1 1 1 0 1 1 0 0   |  | 4 |
|      | +--+--+--+--+--+--+ |  |   |
|      | 0 1 1 1 0 0 0 0 0   |  | 5 |
|      | +--+--+--+--+--+--+ |  |   |
|      | 0 0 0 1 1 1 1 0 0   |  | 6 |
|      | +--+--+--+--+--+--+ |  |   |
|      | 0 0 0 0 0 0 0 0     |  | 7 |
|      | +--+--+--+--+--+--+ |  |   |

Figure 11-2 User Defined 8 x 8 Character Matrix Bit Table

The storage for the character set involves eight consecutive bytes for each character with characters ordered consecutively by their internal code value (see the discussion in Appendix L relating to B55).

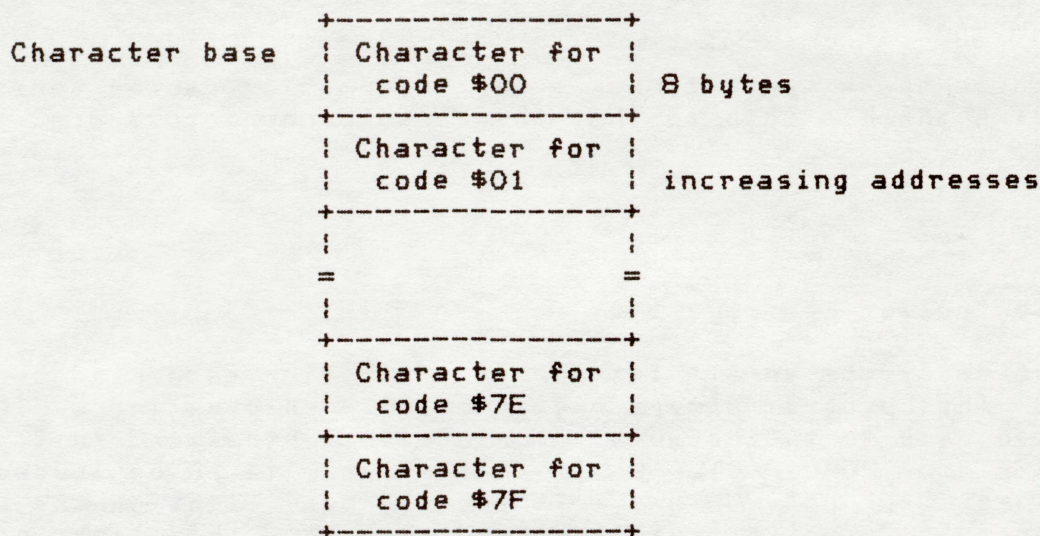


Figure 11-3 Character Base Diagram

#### PLAYER/MISSILE GRAPHICS

The OS makes no use of the player/missile generation capability of the hardware. It can be used independently of the OS with no conflict.

## Hardware Capabilities

The hardware allows a number of independently moveable screen objects of limited width to be positioned and moved about the screen without affecting the "playfield" (bit-mapped graphics or character) data. Priority control allows the various objects to have a display precedence in case of conflict (overlap).

## Conflicts With OS

You must assure that the player/missile data is address-aligned as required by PMBASE [D407]. You also must find a suitable free area that the OS guarantees to be free under all environments.

## READING GAME CONTROLLERS

The OS reads the game controllers (shown below) as part of the stage 2 VBLANK process (see Appendix L J1-9):

- Joysticks/triggers 1-4.
- Paddle controllers/triggers 1-8.
- Driving controllers/triggers 1-4.
- Light pen/trigger

In addition to these controllers, other information can be sensed or sent using the PIA chip to that the console connectors are interfaced.

## Keyboard Controller Sensing

Data can be read from an ATARI keyboard controller connected to the first port. This program alters registers on a chip called a PIA. To set these back to the default values to do further I/O, hit [SYSTEM.RESET] or POKE PACTL,60. If this program is to be loaded from diskette, use LOAD, not RUN and wait for the busy light on the disk drive to go out. Do not execute the program before this light goes out, otherwise the diskette continues to spin.

```
1 GRAPHICS 0
5 PRINT :PRINT " KEYBOARD CONTROLLER DEMO"
10 DIM ROW(3), I$(13), BUTTON$(1)
30 GOSUB 6000
40 FOR CNT=1 TO 4
60 POSITION 2,CNT*2+5:PRINT "CONTROLLER # ";CNT;" ":"";
```

```

70 NEXT CNT
80 FOR CNT=1 TO 4:GOSUB 7000:POSITION 19,CNT+CNT+5:PRINT BUTTON$;
 :NEXT CNT
120 GOTO 80
6000 REM ** SET UP FOR CONTROLLERS **
6010 PORTA=54016:PORTB=54017:PACTL=54018:PBCTL=54019
6020 POKE PACTL,48:POKE PORTA,255:POKE PACTL,52:POKE PORTA,221
6025 POKE PBCTL,48:POKEPORTB,255:POKE PBCTL,52:POKE PORTB,221
6030 ROW(0)=238:ROW(1)=221:ROW(2)=187:ROW(3)=119
6040 I$=" 123456789*0#"
6050 RETURN
7000 REM ** RETURN BUTTON$ WITH CHARACTER FOR BUTTON WHICH HAS
 BEEN PRESSED ON CONTROLLER CNT (1-4). **
7001 REM ** NOTE: A 1 WILL BE RETURNED IF NO CONTROLLER IS
 CONNECTED. **
7002 REM ** A SPACE WILL BE RETURNED IF THE CONTROLLER IS
 CONNECTED BUT NO KEY HAS BEEN PRESSED. **
7003 PORT=PORTA:IF CNT>2 THEN PORT=PORTB
7005 P=1
7008 PAD=CNT+CNT-2
7010 FOR J=0 TO 3
7020 POKE PORT,ROW(J)
7030 FOR I=1 TO 10:NEXT I
7050 IF PADDLE(PAD+1)>10 THEN P=J+J+J+2:GOTO 7090
7060 IF PADDLE(PAD)>10 THEN P=J+J+J+3:GOTO 7090
7070 IF STRIG(CNT-1)=0 THEN P=J+J+J+4:GOTO 7090
7080 NEXT J
7090 BUTTON$=I$(P,P)
7095 RETURN

```

Figure 11-4 Reading Data From an ATARI Keyboard Controller

The table below shows the variable/register values used for reading a keyboard controller from each of the four controller ports.

|           | Port 1  | Port 2 | Port 3  | Port 4  |
|-----------|---------|--------|---------|---------|
| PORT A    |         |        |         |         |
| direction | 0F      | F0     | -       | -       |
| bits      |         |        |         |         |
| PORT B    |         |        |         |         |
| direction | -       | -      | 0F      | F0      |
| bits      |         |        |         |         |
| Port A    | FE, FD, | EF, DF |         |         |
| row sel   | FB, F7  | BF, 7F | -       | -       |
| ect       |         |        |         |         |
| Port B    |         |        | FE, FD, | EF, DF, |
| row se-   | -       | -      | FB, F7  | BF, 7F  |
| lect      |         |        |         |         |
| Column 1  | PADDL1  | PADDL3 | PADDL5  | PADDL7  |
| Sense     |         |        |         |         |
| Column 2  | PADDL0  | PADDL2 | PADDL4  | PADDL6  |
| Sense     |         |        |         |         |
| Column 3  | STRIG0  | STRIG1 | STRIG2  | STRIG3  |
| Sense     |         |        |         |         |

Figure 11-5 ATARI Keyboard Controller Variable/Register Value Table

#### Front Panel Connectors as I/O Ports

The three pages that follow show how some of the pins in the front panel (game controller) connectors can be used as general I/O pins.

#### Hardware Information

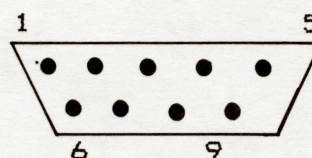
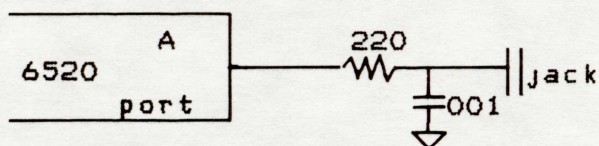
PIA (6520 / 6820)

Out: TTL levels, 1 load

In : TTL levels, 1 load

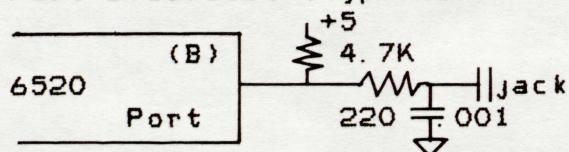
For more information refer to 6520 chip manual.

# Port A Circuit (typical):



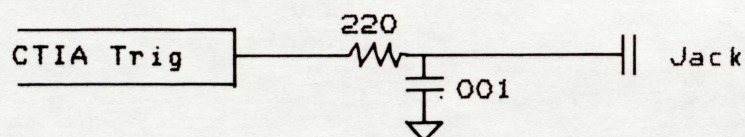
Male connector, FRONT view  
Pin 8 = Ground  
Pin 7 = Vcc 8+5v \*)

## Port B Circuit (typical):



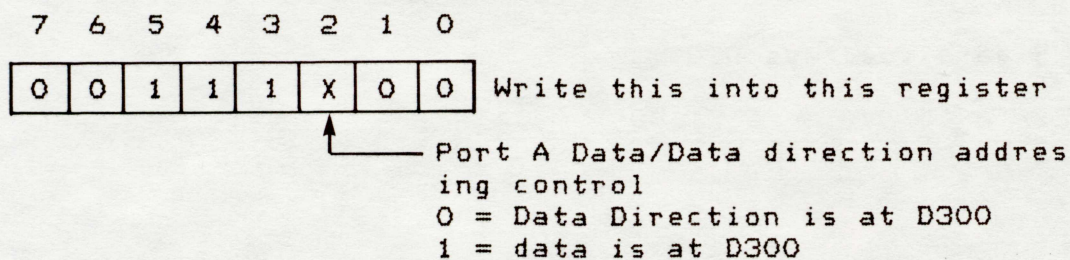
Note: 50mA maximum  
total external drain  
on power supply allowed

## "Trigger" Port Circuit (typical):

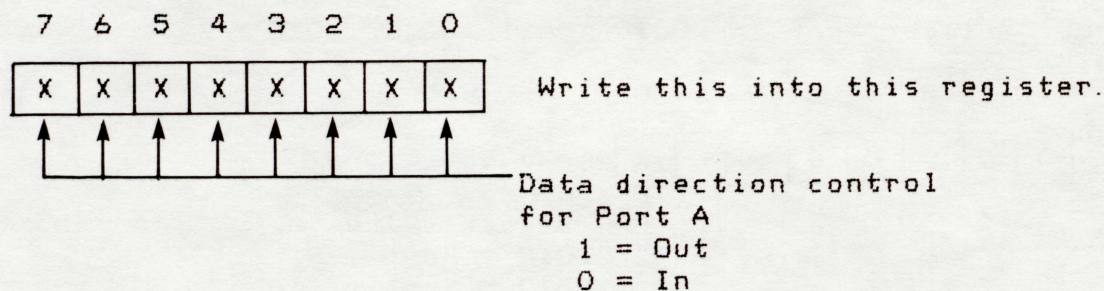


## Software Information

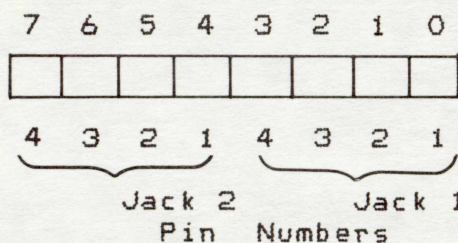
6520 PIA: (This also pertains to all of the following: \*\*)  
Port A control (address D302)



Port A data direction (address D300)

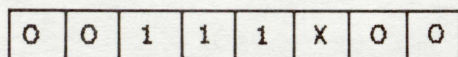


Port A data (address D300)



Read or Write this register

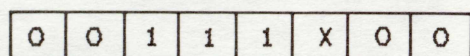
Port B Control (address D303)



6520 PIA:

Port B Control (address D303)

7 6 5 4 3 2 1 0

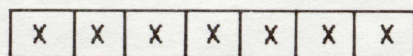


write this into this register

Port B Data/Data direction  
addressing control  
0 = D301 contains data  
direction  
1 = \$D301 contains

Port B data direction (address D301)

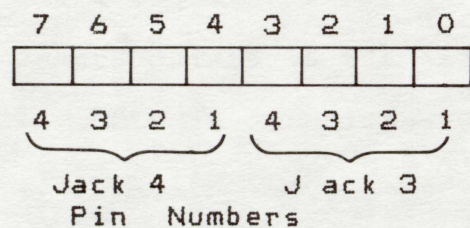
7 6 5 4 3 2 1



write this into this register

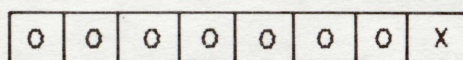
data direction control for Port B  
1 = Out  
0 = In

Port B data (address D301)



Four "Trigger" ports: D010, D011, D012, D013

7 6 5 4 3 2 1 0



Read this port

Trigger Value  
D010 = Port 1 Pin 6  
D013 = Port 4 pin 6

## Other Miscellaneous Software Information

- 1). The OS sets up all PIA ports as inputs during initialization.
- 2). The OS usually reads the above once per television frame (during vertical-blank) into RAM as follows:

| Data Base Name | Address | Data                                          | Pins S                            |
|----------------|---------|-----------------------------------------------|-----------------------------------|
| STICK0         | 0278    | 7 6 5 4 3 2 1 0<br><div>0 0 0 0 X X X X</div> | Jack 1, pins 4,3,2,<br>if 10053,7 |
| STICK1         | 0729    |                                               | Jack 2, Pins 4,3,2,1              |
| STICK2         | 027A    |                                               | Jack 3, Pins 4,3,2,1              |
| STICK3         | 027B    |                                               | Jack 4, Pins 4,3,2,1              |
| STRIG0         | 0284    |                                               | Jack 1, Pin 6                     |
| STRIG1         | 0285    | 7 6 5 4 3 2 1 0<br><div>0 0 0 0 0 0 0 0</div> | Jack 2, Pin 6                     |
| STRIG2         | 0286    |                                               | Jack 3, Pin 6                     |
| STRIG3         | 0287    |                                               | Jack 4, Pin 6                     |
| PADDL1         | 0270    | 7 6 5 4 3 2 1 0<br><div>X X X X X X X X</div> | Jack 1, Pin 5                     |
| PADDL3         | 0272    |                                               | Jack 2, Pin 5                     |
| PADDL5         | 0274    |                                               | Jack 3, Pin 5                     |
| PADDL7         | 0276    |                                               | Jack 4, Pin 5                     |
| PADDL0         | 0271    |                                               | Jack 1, Pin 9                     |
| PADDL2         | 0273    |                                               | Jack 2, Pin 9                     |
| PADDL4         | 0275    |                                               | Jack 3, Pin 9                     |
| PADDL 6        | 0277    |                                               | Jack 4, Pin 9                     |

Figure 11-6 Using Front Panel Connectors As I/O Ports: Pin Function Tables

\* Pins 5 and 9 are read through the paddle controller circuitry a nominal value of 7 indicates that the pin is high (or floating) and a nominal value of 228 indicates that the pin is pulled low.

## Appendix A -- CIO COMMAND BYTE VALUES

The following hex values are known to be legitimate CIO commands.

### Most handlers:

- 03 -- OPEN
- 05 -- GET RECORD
- 07 -- GET CHARACTERS
- 09 -- PUT RECORD
- 0B -- PUT CHARACTERS
- 0C -- CLOSE
- 0D -- GET STATUS

### Display Handler only:

- 11 -- FILL
- 12 -- DRAW

### Diskette File Manager only:

- 20 -- RENAME
- 21 -- DELETE
- 22 -- FORMAT
- 23 -- LOCK
- 24 -- UNLOCK
- 25 -- POINT
- 26 -- NOTE

## Appendix B -- CIO STATUS BYTE VALUES

Shown below are the known CIO STATUS BYTE values.

01 (001) -- OPERATION COMPLETE (NO ERRORS)

80 (128) -- [BREAK] KEY ABORT  
81 (129) -- IOCB ALREADY IN USE (OPEN)  
82 (130) -- NON-EXISTENT DEVICE  
83 (131) -- OPENED FOR WRITE ONLY  
84 (132) -- INVALID COMMAND  
85 (133) -- DEVICE OR FILE NOT OPEN  
86 (134) -- INVALID IOCB NUMBER (Y reg only)  
87 (135) -- OPENED FOR READ ONLY  
88 (136) -- END OF FILE  
89 (137) -- TRUNCATED RECORD  
8A (138) -- DEVICE TIMEOUT (DOESN'T RESPOND)  
8B (139) -- DEVICE NAK  
8C (140) -- SERIAL BUS INPUT FRAMING ERROR  
8D (141) -- CURSOR out-of-range  
8E (142) -- SERIAL BUS DATA FRAME OVERRUN ERROR  
8F (143) -- SERIAL BUS DATA FRAME CHECKSUM ERROR  
90 (144) -- DEVICE DONE ERROR  
91 (145) -- BAD SCREEN MODE  
92 (146) -- FUNCTION NOT SUPPORTED BY HANDLER  
93 (147) -- INSUFFICIENT MEMORY FOR SCREEN MODE

A0 (160) -- DISK DRIVE # ERROR  
A1 (161) -- TOO MANY OPEN DISK FILES  
A2 (162) -- DISK FULL  
A3 (163) -- FATAL DISK I/O ERROR  
A4 (164) -- INTERNAL FILE # MISMATCH  
A5 (165) -- FILE NAME ERROR  
A6 (166) -- POINT DATA LENGTH ERROR  
A7 (167) -- FILE LOCKED  
A8 (168) -- COMMAND INVALID FOR DISK  
A9 (169) -- DIRECTORY FULL (64 FILES)  
AA (170) -- FILE NOT FOUND  
AB (171) -- POINT INVALID

## Appendix C -- SIO STATUS BYTE VALUES

Shown below are the known SIO STATUS BYTE hexadecimal values.

01 (001) -- OPERATION COMPLETE (NO ERRORS)  
8A (138) -- DEVICE TIMEOUT (DOESN'T RESPOND)  
8B (139) -- DEVICE NAK  
8C (140) -- SERIAL BUS INPUT FRAMING ERROR  
8E (142) -- SERIAL BUS DATA FRAME OVERRUN ERROR  
8F (143) -- SERIAL BUS DATA FRAME CHECKSUM ERROR  
90 (144) -- DEVICE DONE ERROR

## Appendix D -- ATASCII CODES

|    | ØX  | 2X    | 4X | 6X     | 8X   | AX | CX | EX   |
|----|-----|-------|----|--------|------|----|----|------|
| ØØ |     | Space | @  |        |      |    |    |      |
| Ø1 |     | !     | A  | a      |      |    |    |      |
| Ø2 |     | "     | B  | b      |      |    |    |      |
| Ø3 |     | #     | C  | c      |      |    |    |      |
| Ø4 |     | \$    | D  | d      |      |    |    |      |
| Ø5 |     | %     | E  | e      |      |    |    |      |
| Ø6 |     | &     | F  | f      |      |    |    |      |
| Ø7 |     | '     | G  | g      |      |    |    |      |
| Ø8 |     | (     | H  | h      |      |    |    |      |
| Ø9 |     | )     | I  | i      |      |    |    |      |
| ØA |     | *     | J  | j      |      |    |    |      |
| ØB |     | +     | K  | k      |      |    |    |      |
| ØC |     | ,     | L  | l      |      |    |    |      |
| ØD |     | -     | M  | m      |      |    |    |      |
| ØE |     | .     | N  | n      |      |    |    |      |
| ØF |     | /     | O  | o      |      |    |    |      |
| 1Ø |     | Ø     | P  | p      |      |    |    |      |
| 11 |     | 1     | Q  | q      |      |    |    |      |
| 12 |     | 2     | R  | r      |      |    |    |      |
| 13 |     | 3     | S  | s      |      |    |    |      |
| 14 |     | 4     | T  | t      |      |    |    |      |
| 15 |     | 5     | U  | u      |      |    |    |      |
| 16 |     | 6     | V  | v      |      |    |    |      |
| 17 |     | 7     | W  | w      |      |    |    |      |
| 18 |     | 8     | X  | x      |      |    |    |      |
| 19 |     | 9     | Y  | y      |      |    |    |      |
| 1A |     | :     | Z  | z      |      |    |    |      |
| 1B | ESC | ;     | [  |        | EOL  |    |    |      |
| 1C |     | <     | \  |        | DEL  |    |    |      |
| 1D |     | =     | ]  | CLEAR  | LINE |    |    |      |
| 1E |     | >     | ^  | BACKSP | INS  |    |    | BELL |
| 1F |     | ?     | _  | TAB    | CLB  |    |    | DEL  |
|    |     |       |    |        | SET  |    |    | CHAR |
|    |     |       |    |        | TAB  |    |    | CHAR |

# Appendix E -- DISPLAY CODES (ATASCII)

|    | 0X | 2X    | 4X | 6X | 8X                                                         | AX | CX | EX |
|----|----|-------|----|----|------------------------------------------------------------|----|----|----|
| 00 |    | Space | @  |    |                                                            |    |    |    |
| 01 |    | !     | A  | a  |                                                            |    |    |    |
| 02 |    | "     | B  | b  |                                                            |    |    |    |
| 03 |    | #     | C  | c  |                                                            |    |    |    |
| 04 |    | \$    | D  | d  |                                                            |    |    |    |
| 05 |    | %     | E  | e  |                                                            |    |    |    |
| 06 |    | &     | F  | f  |                                                            |    |    |    |
| 07 |    | '     | G  | g  |                                                            |    |    |    |
| 08 |    | (     | H  | h  |                                                            |    |    |    |
| 09 |    | )     | I  | i  |                                                            |    |    |    |
| 0A |    | *     | J  | j  |                                                            |    |    |    |
| 0B |    | +     | K  | k  |                                                            |    |    |    |
| 0C |    | ,     | L  | l  |                                                            |    |    |    |
| 0D |    | -     | M  | m  |                                                            |    |    |    |
| 0E |    | .     | N  | n  |                                                            |    |    |    |
| 0F |    | /     | O  | o  |                                                            |    |    |    |
| 10 |    |       | P  | p  | CODES 80-FF SHOW AS<br>THE INVERSE VIDEO<br>OF CODES 00-7F |    |    |    |
| 11 |    | 0     | Q  | q  |                                                            |    |    |    |
| 12 |    | 1     | R  | r  |                                                            |    |    |    |
| 13 |    | 2     | S  | s  |                                                            |    |    |    |
| 14 |    | 3     | T  | t  |                                                            |    |    |    |
| 15 |    | 4     | U  | u  |                                                            |    |    |    |
| 16 |    | 5     | V  | v  |                                                            |    |    |    |
| 17 |    | 6     | W  | w  |                                                            |    |    |    |
| 18 |    | 7     | X  | x  |                                                            |    |    |    |
| 19 |    | 8     | Y  | y  |                                                            |    |    |    |
| 1A |    | 9     | Z  | z  |                                                            |    |    |    |
| 1B |    | :     | [  |    |                                                            |    |    |    |
| 1C |    | ;     | \  |    |                                                            |    |    |    |
| 1D |    | <     | ]  |    |                                                            |    |    |    |
| 1E |    | =     | ^  |    |                                                            |    |    |    |
| 1F |    | >     | _  |    |                                                            |    |    |    |
|    |    | ?     |    |    |                                                            |    |    |    |

# Appendix F -- KEYBOARD CODES (ATASCII)

| CTRL |          |    | SHIFT &<br>LOWER |         |    | SHIFT |   |    | LOWER |         |    |
|------|----------|----|------------------|---------|----|-------|---|----|-------|---------|----|
| 00   | ,        | 20 | 20               | <space> | 21 | 40    | @ | 35 | 60    | ^.      | 22 |
| 01   | A        | 3F | 21               | !       | 1F | 41    | A | 3F | 61    | a       | 3F |
| 02   | B        | 15 | 22               | "       | 1E | 42    | B | 15 | 62    | b       | 15 |
| 03   | C        | 12 | 23               | #       | 1A | 43    | C | 12 | 63    | c       | 12 |
| 04   | D        | 3A | 24               | \$      | 18 | 44    | D | 3A | 64    | d       | 3A |
| 05   | E        | 2A | 25               | %       | 1D | 45    | E | 2A | 65    | e       | 2A |
| 06   | F        | 38 | 26               | &       | 1B | 46    | F | 38 | 66    | f       | 38 |
| 07   | G        | 3D | 27               | '       | 33 | 47    | G | 3D | 67    | g       | 3D |
| 08   | H        | 39 | 28               | (       | 30 | 48    | H | 39 | 68    | h       | 39 |
| 09   | I        | 0D | 29               | )       | 32 | 49    | I | 0D | 69    | i       | 0D |
| 0A   | J        | 01 | 2A               | *       | 07 | 4A    | J | 01 | 6A    | j       | 01 |
| 0B   | K        | 05 | 2B               | +       | 06 | 4B    | K | 05 | 6B    | k       | 05 |
| 0C   | L        | 00 | 2C               | ,       | 20 | 4C    | L | 00 | 6C    | l       | 00 |
| 0D   | M        | 25 | 2D               | -       | 0E | 4D    | M | 25 | 6D    | m       | 25 |
| 0E   | N        | 23 | 2E               | .       | 22 | 4E    | N | 23 | 6E    | n       | 23 |
| 0F   | O        | 08 | 2F               | /       | 26 | 4F    | O | 08 | 6F    | o       | 08 |
| 10   | P        | 0A | 30               | 0       | 32 | 50    | P | 0A | 70    | p       | 0A |
| 11   | Q        | 2F | 31               | 1       | 1F | 51    | Q | 2F | 71    | q       | 2F |
| 12   | R        | 28 | 32               | 2       | 1E | 52    | R | 28 | 72    | r       | 28 |
| 13   | S        | 3E | 33               | 3       | 1A | 53    | S | 3E | 73    | s       | 3E |
| 14   | T        | 2D | 34               | 4       | 18 | 54    | T | 2D | 74    | t       | 2D |
| 15   | U        | 0B | 35               | 5       | 1D | 55    | U | 0B | 75    | u       | 0B |
| 16   | V        | 10 | 36               | 6       | 1B | 56    | V | 10 | 76    | v       | 10 |
| 17   | W        | 2E | 37               | 7       | 33 | 57    | W | 2E | 77    | w       | 2E |
| 18   | X        | 16 | 38               | 8       | 35 | 58    | X | 16 | 78    | x       | 16 |
| 19   | Y        | 2B | 39               | 9       | 30 | 59    | Y | 2B | 79    | y       | 2B |
| 1A   | Z        | 17 | 3A               | :       | 02 | 5A    | Z | 17 | 7A    | z       | 17 |
| 1B   | <esc>    | 1C | 3B               | ;       | 0D | 5B    | [ | 20 | 7B    | ,       | 02 |
| 1C   | ^<up>    | 0E | 3C               | <       | 36 | 5C    | \ | 06 | 7C    | !       | 0F |
| 1D   | ^<down>  | 0F | 3D               | =       | 0F | 5D    | ] | 22 | 7D    | <clear> | 36 |
| 1E   | ^<left>  | 06 | 3E               | >       | 37 | 5E    | ^ | 07 | 7E    | <back>  | 34 |
| 1F   | ^<right> | 07 | 3F               | ?       | 26 | 5F    | _ | 0E | 7F    | <tab>   | 2C |

80-9A /\ 00-1A

9B <return> and ^3 0C, 1A

9C s<del> 34

9D s<insert> 37

9E ^<tab> 2C

9F s<tab> 2C

A0-FC /\ 20-7C

FD ^2 1E

FE ^<del> 34

FF ^<insert> 37

<clear> ::= s< or ^<

<return> ::= <return> or s<return> or ^<return>

<esc> ::= <esc> or s<esc> or ^<esc>

<space> ::= <space> or s<space> or ^<space>

Where: s as a prefix indicates [SHIFT].

^ as a prefix indicates [CTRL].

/\ as a prefix indicates ATARI key inverse active.

## Appendix G -- PRINTER CODES (ATASCII)

Character set for "normal" mode printing:

|            |      |            |
|------------|------|------------|
| 20 <space> | 40 @ | 60 `       |
| 21 !       | 41 A | 61 a       |
| 22 "       | 42 B | 62 b       |
| 23 #       | 43 C | 63 c       |
| 24 \$      | 44 D | 64 d       |
| 25 %       | 45 E | 65 e       |
| 26 &       | 46 F | 66 f       |
| 27 '       | 47 G | 67 g       |
| 28 (       | 48 H | 68 h       |
| 29 )       | 49 I | 69 i       |
| 2A *       | 4A J | 6A j       |
| 2B +       | 4B K | 6B k       |
| 2C ,       | 4C L | 6C l       |
| 2D -       | 4D M | 6D m       |
| 2E .       | 4E N | 6E n       |
| 2F /       | 4F O | 6F o       |
| 30 0       | 50 P | 70 p       |
| 31 1       | 51 Q | 71 q       |
| 32 2       | 52 R | 72 r       |
| 33 3       | 53 S | 73 s       |
| 34 4       | 54 T | 74 t       |
| 35 5       | 55 U | 75 u       |
| 36 6       | 56 V | 76 v       |
| 37 7       | 57 W | 77 w       |
| 38 8       | 58 X | 78 x       |
| 39 9       | 59 Y | 79 y       |
| 3A :       | 5A Z | 7A z       |
| 3B ;       | 5B [ | 7B {       |
| 3C <       | 5C \ | 7C         |
| 3D =       | 5D ] | 7D }       |
| 3E >       | 5E ^ | 7E ~       |
| 3F ?       | 5F _ | 7F <space> |

Note: The following codes print differently than defined by the ATASCII definition.

- 00 through 1F print blank.
- 60 prints ` instead of "diamond".
- 7B prints { instead of "spade".
- 7D prints } instead of "clear".
- 7E prints ~ instead of "backspace".
- 7F prints blank instead of "tab".

Character set for "sideways" mode printing:

|    |    |    |        |    |        |
|----|----|----|--------|----|--------|
|    | 40 | @  | 60     | @  |        |
|    | 41 | A  | 61     | A  |        |
|    | 42 | B  | 62     | B  |        |
|    | 43 | C  | 63     | C  |        |
|    | 44 | D  | 64     | D  |        |
|    | 45 | E  | 65     | E  |        |
|    | 46 | F  | 66     | F  |        |
|    | 47 | G  | 67     | G  |        |
|    | 48 | H  | 68     | H  |        |
|    | 49 | I  | 69     | I  |        |
|    | 4A | J  | 6A     | J  |        |
|    | 4B | K  | 6B     | K  |        |
|    | 4C | L  | 6C     | L  |        |
|    | 4D | M  | 6D     | M  |        |
|    | 4E | N  | 6E     | N  |        |
|    | 4F | O  | 6F     | O  |        |
| 30 | 0  | 50 | P      | 70 | P      |
| 31 | 1  | 51 | Q      | 71 | Q      |
| 32 | 2  | 52 | R      | 72 | R      |
| 33 | 3  | 53 | S      | 73 | S      |
| 34 | 4  | 54 | T      | 74 | T      |
| 35 | 5  | 55 | U      | 75 | U      |
| 36 | 6  | 56 | V      | 76 | V      |
| 37 | 7  | 57 | W      | 77 | W      |
| 38 | 8  | 58 | X      | 78 | X      |
| 39 | 9  | 59 | Y      | 79 | Y      |
| 3A | :  | 5A | Z      | 7A | Z      |
| 3B | ;  | 5B | [      | 7B | [      |
| 3C | <  | 5C | \      | 7C | \      |
| 3D | =  | 5D | ]      | 7D | ]      |
| 3E | >  | 5E | <up>   | 7E | <up>   |
| 3F | ?  | 5F | <left> | 7F | <left> |

Note: the following codes print differently than defined by the ATASCII definition.

00 through 2F print blank.

5E prints "up arrow" instead of .

5F prints "left arrow" instead of \_.

60 through 7F repeats 40 through 5F instead of proper set.

# Appendix H -- SCREEN MODE CHARACTERISTICS

| Mode # | Horiz. Posit. | Vert. W/O Sp | Vert. W Sp | Colors | Data Value                                  | Color Reg.                           | Memory Reqd.<br>(split) (full) |      |
|--------|---------------|--------------|------------|--------|---------------------------------------------|--------------------------------------|--------------------------------|------|
| 0      | 40            | 24           | --         | 2      | backgd.<br>00-FF<br>"                       | BAK<br>PF 2<br>PF 1*                 | 992                            | 992  |
| 1      | 20            | 24           | 20         | 5      | backgd.<br>00-3F<br>40-7F<br>80-BF<br>C0-FF | BAK<br>PF 0<br>PF 1<br>PF 2<br>PF 3  | 674                            | 672  |
| 2      | 20            | 12           | 10         | 5      | backgd.<br>00-3F<br>40-7F<br>80-BF<br>C0-FF | BAK<br>PF 0<br>PF 1<br>PF 2<br>PF 3  | 424                            | 420  |
| 3      | 40            | 24           | 20         | 4      | 0<br>1<br>2<br>3                            | BAK<br>PF 0<br>PF 1<br>PF 2          | 434                            | 432  |
| 4      | 80            | 48           | 40         | 2      | 0<br>1                                      | BAK<br>PF 0                          | 694                            | 696  |
| 5      | 80            | 48           | 40         | 4      | 0<br>1<br>2<br>3                            | BAK<br>PF 0<br>PF 1<br>PF 2          | 1174                           | 1176 |
| 6      | 160           | 96           | 80         | 2      | 0<br>1                                      | BAK<br>PF 0                          | 2174                           | 2184 |
| 7      | 160           | 96           | 80         | 4      | 0<br>1<br>2<br>3                            | BAK<br>PF 0<br>PF 1<br>PF 2          | 4190                           | 4200 |
| 8      | 320           | 192          | 160        | 2      | 0<br>1                                      | PF 2<br>PF 1*                        | 8112                           | 8138 |
| 9      | 80            | 192          | --         | 1      | Note 2                                      |                                      |                                | 8138 |
| 10     | 80            | 192          | --         | 9      | 0<br>1<br>2<br>3<br>4                       | PM 0<br>PM 1<br>PM 2<br>PM 3<br>PF 0 |                                | 8138 |

|   |      |
|---|------|
| 5 | PF 1 |
| 6 | PF 2 |
| 7 | PF 3 |
| 8 | BAK  |
| 9 | BAK  |
| A | BAK  |
| B | BAK  |
| C | PF 0 |
| D | PF 1 |
| E | PF 2 |
| F | PF 3 |

11 80 192 -- 16 Note 3 8138

#### Notes:

- \* Uses color of PF 2, lum of PF 1.
- 2 Uses color of BAK, lum of data value (\$0-F).
- 3 Uses color of data value (\$0-F), lum of BAK.

PF x ::= Playfield color register x.

PM x ::= Player/Missile Graphics color register x.

BAK ::= Background color register (also known as PF 4).

The default values for the color registers are shown below:

|     |   |      |
|-----|---|------|
| BAK | = | \$00 |
| PF0 | = | \$28 |
| PF1 | = | \$CA |
| PF2 | = | \$94 |
| PF3 | = | \$46 |

The form of a color register byte is shown below:

```
 7 6 5 4 3 2 1 0
+---+---+---+---+
! color ! lum !0!
+---+---+---+---+
```

Where: color (hex values)

lum

|                  |                       |
|------------------|-----------------------|
| 0 = gray         | 0 = minimum luminance |
| 1 = light orange | 1 = !                 |
| 2 = orange       | 2 = !                 |
| 3 = red orange   | 3 = (increasing       |
| 4 = pink         | 4 = luminance)        |
| 5 = purple       | 5 = !                 |
| 6 = purple-blue  | 6 = !                 |
| 7 = blue         | 7 = maximum luminance |
| 8 = blue         |                       |
| 9 = light blue   |                       |
| A = turquoise    |                       |
| B = green-blue   |                       |
| C = green        |                       |
| D = yellow-green |                       |
| E = orange-green |                       |
| F = light orange |                       |

## Appendix I -- SERIAL BUS ID AND COMMAND SUMMARY

### Serial bus device IDs

|                  |       |         |
|------------------|-------|---------|
| Floppy diskettes | D1-D4 | \$31-34 |
| Printer          | P1    | \$40    |
| RS-232-C         | R1-R4 | \$50-53 |

### Serial bus control codes

|          |              |
|----------|--------------|
| ACK      | - \$41 ('A') |
| NAK      | - \$4E ('N') |
| COMPLETE | - \$43 ('C') |
| ERR      | - \$45 ('E') |

### Serial bus command codes

|               |              |              |
|---------------|--------------|--------------|
| READ          | - \$52 ('R') | Disk         |
| WRITE         | - \$57 ('W') | Printer/Disk |
| STATUS        | - \$53 ('S') | Printer/Disk |
| PUT(no check) | - \$50 ('P') | Disk         |
| FORMAT        | - \$21 ('!') | Disk         |
| READ ADDRESS  | - \$54 ('T') |              |
| READ SPIN     | - \$51 ('Q') | Disk         |
| MOTOR ON      | - \$55 ('U') | Disk         |
| VERIFY SECTOR | - \$56 ('V') | Disk         |

## Appendix J -- ROM VECTORS

The fixed address OS ROM JMP vectors are shown below; at each address is a JMP instruction to the indicated routine.

| Name   | Addr | Reference | Function                          |
|--------|------|-----------|-----------------------------------|
| DISKIV | E450 | *         | Diskette Handler initialization   |
| DSKINV | E453 | 5.4.2     | Diskette Handler entry.           |
| CIOV   | E456 | 5.2       | CIO utility entry.                |
| SIOV   | E459 | 9.3       | SIO utility entry.                |
| SETVBV | E45C | 6.7.2     | Set System Timers routine.        |
| SYSVBV | E45F | 6.3       | Stage 1 VBLANK entry.             |
| XITVBV | E462 | 6.3       | Exit VBLANK entry.                |
| SIOINV | E465 | *         | SIO utility initialization.       |
| SENDEV | E468 | *         | Send enable routine.              |
| INTINV | E46B | *         | Interrupt Handler initialization. |
| CIOINV | E46E | *         | CIO utility initialization.       |
| BLKBDV | E471 | 3.1.1     | Blackboard mode entry.            |
| WARMSV | E474 | 7.        | Warmstart ([SYSTEM.RESET]) entry. |
| COLDSV | E477 | 7.        | Coldstart (power-up) entry.       |
| RBLOKV | E47A | *         | Cassette-read block entry.        |
| CSOPIV | E47D | *         | Cassette-OPEN input entry.        |

\* These vectors are for OS internal use only.

The fixed address Floating Point Package ROM routine entry point addresses are shown below; complete descriptions of the corresponding routines are provided in Section 8.

|        |      |                            |
|--------|------|----------------------------|
| AFP    | D800 | ASCII to FP convert.       |
| FASC   | D8E6 | FP to ASCII convert.       |
| IFP    | D9AA | Integer to FP convert.     |
| FPI    | D9D2 | FP to integer convert.     |
| FADD   | DA66 | FP add.                    |
| FSUB   | DA60 | FP subtract.               |
| FMUL   | DADB | FP multiply                |
| FDIV   | DB28 | FP divide.                 |
| LOG    | DECD | FP base e logarithm.       |
| LOG10  | DED1 | FP base 10 logarithm.      |
| EXP    | DDC0 | FP base e exponentiation.  |
| EXP10  | DDCC | FP base 10 exponentiation. |
| PLYEVL | DD40 | FP polynomial evaluation.  |
| ZFRO   | DA44 | Clear FRO.                 |
| ZF1    | DA46 | Clear FP number.           |
| FLDOR  | DD89 | Load FP number.            |
| FLDOP  | DD8D | Load FP number.            |
| FLD1R  | DD98 | Load FP number.            |
| FLD1P  | DD9C | Load FP number.            |
| FSTOR  | DDA7 | Store FP number.           |
| FSTOP  | DDAB | Store FP number.           |
| FMOVE  | DDB6 | Move FP number.            |

The base addresses of the Handler vectors for the resident handlers are shown below:

|                      |      |
|----------------------|------|
| Screen Editor (E)    | E400 |
| Display Handler (S)  | E410 |
| Keyboard Handler (K) | E420 |
| Printer Handler (P)  | E430 |
| Cassette Handler (C) | E440 |

See Section 5 for the format of the entry for each Handler.

The 6502 Computer interrupt vector values are shown below:

| Function | Address | Value |
|----------|---------|-------|
| NMI      | FFFA    | E7B4  |
| RESET    | FFAC    | E477  |
| IRQ      | FFFE    | E6FE  |

## Appendix K -- DEVICE CHARACTERISTICS

This appendix describes the physical characteristics of the devices that interface to the ATARI 400 and ATARI 800 Home Computers. Where applicable, data capacity, data transfer rate, storage format, SIO interface, and cabling will be detailed.

### KEYBOARD

The keyboard input rate is limited by the OS keyboard reading procedure to be 60 characters per second. The code for each key is shown in Table 5-4. The keyboard hardware has no buffering and is rate-limited by the debounce algorithm used.

### DISPLAY

The television screen display generator has many capabilities that are not used by the Display Handler (as described in Section 5 and shown in Appendix H). There are additional display modes, object generators, hardware display scrolling, and many other features that are described in the ATARI Home Computer Hardware Manual.

Since all display data is stored in RAM, the display data update rate is limited primarily by the software routines that generate and format the data and access the RAM. The generation of the display from the RAM is accomplished by the ANTIC and CTIA or GTIA chips using Direct Memory Access (DMA) to access the RAM data.

The internal storage formats for display data for the various modes are detailed in the ATARI Home Computer Hardware Manual.

### ATARI 410 PROGRAM RECORDER

The ATARI 410 Program Recorder has the following characteristics:

#### DATA CAPACITY:

100 characters per C-60 tape (unformatted).

#### DATA TRANSFER RATES:

\* 600 Baud (60 characters per second)

\*Note: The OS has the ability to adjust to different tape speeds (447 - 895 Baud).

## STORAGE FORMAT:

Tapes are recorded in 1/4 track stereo format at 1 7/8 inches per second. The tape can be recorded in both directions, where tracks 1 and 2 are side A left and right; and tracks 3 and 4 are side B right and left (industry standard). On each side, the left channel (1 or 4) is used for audio and the right channel (2 and 3) is used for digital information.

The audio channel is recorded the normal way. The digital channel is recorded using the POKEY two-tone mode producing FSK data at up to 600 baud. The MARK frequency is 5327 Hz and the SPACE frequency is 3995 Hz. The transmission of data is asynchronous byte serial as seen from the computer; POKEY reads or writes a bit serial FSK sequence for each byte, in the following order:

```
1 start bit (SPACE)
data bit 0 -+
data bit 1 !
 +- 0 = SPACE, 1 = MARK.
data bit 6 !
data bit 7 -+
1 stop bit (MARK)
```

The only control the computer has over tape motion is motor start/stop; and this only if the PLAY button is pressed by the user. In order for recording to take place, the user must press both the REC and PLAY buttons on the cassette. The computer has no way to sense the position of these buttons, nor even if an ATARI 410 Program Recorder is cabled to the computer, so the user must be careful when using this device.

## SIO INTERFACE

The cassette device utilizes portions of the serial bus hardware, but does not follow any of the protocol as defined in Section 9.

## ATARI 820[TM] 40-COLUMN IMPACT PRINTER

The ATARI 820 Printer has the following characteristics:

### DATA CAPACITY:

40 characters per line (normal printing)  
29 characters per line (sideways printing)

### DATA TRANSFER RATES:

Bus rate: xx characters per second.  
Print time (burst): xx characters per second.  
Print time (average): xx characters per second.

#### STORAGE FORMAT:

3 7/8 inch wide paper.  
5X7 dot matrix, impact printing.

#### Normal format --

40 characters per line.  
6 lines per inch (vertical).  
12 characters per inch (horizontal).

#### Sideways format --

29 characters per line.  
6 lines per inch (vertical).  
9 characters per inch (horizontal).

#### SIO INTERFACE

The controller serial bus ID is \$40.

The controller supports the following SIO commands (see Section 5 for more information regarding the Handler and Section 9 for a general discussion of bus commands):

#### GET STATUS

The computer sends a command frame of the format shown below:

Device ID = \$40.  
Command byte = \$53.  
auxiliary 1 = doesn't matter.  
auxiliary 2 = doesn't matter.  
Checksum = checksum of bytes above.

The printer controller responds with a data frame of the format shown earlier in this appendix as part of the GET STATUS discussion.

#### PRINT LINE

The computer sends a command frame of the format shown below:

Device ID = \$40.  
Command byte = \$57.

auxiliary 1 = doesn't matter.  
auxiliary 2 = \$4E for normal print or \$53 for sideways.  
Checksum = checksum of bytes above.

The computer sends a data frame of the format shown below:

Leftmost character of line (column 1).  
Next character of line (column 2).  
.  
.  
Rightmost character of line (column 40 or 29).  
Checksum byte.

Note that the data frame size is variable, either 41 or 30 bytes in length, depending upon the print mode specified in the command frame.

## ATARI 810 DISK DRIVE

The ATARI 810[TM] Disk Drive has the following characteristics:

### DATA CAPACITY:

720 sectors of 128 bytes each (Disk Handler format).  
709 sectors of 125 data bytes each (Disk File Manager format).

### DATA TRANSFER RATES:

Bus rate: 1920 characters per second.  
Seek time: 5.25 msec. per track + 10 to 210 msec.  
Rotational latency: 104 msec maximum (288 rpm).

### STORAGE FORMAT:

5 1/4 inch diskette, soft sectored by the controller.  
40 tracks per diskette.  
18 sectors per track.  
128 bytes per sector.  
Controlled by National INS1771-1 formatter/controller chip.  
Sector sequence per track is: 18, 1, 3, 5, 7, 9, 11, 13, 15,  
17, 2, 4, 6, 8, 10, 12, 14, 16

### SIO INTERFACE

The controller serial bus IDs range from \$31 (for 'D1') to \$34 (for 'D4').

The controller supports the following SIO commands (see earlier in this Appendix for information about the Diskette Handler and Section 9 for a general discussion of bus commands):

#### GET STATUS

The computer sends a command frame of the format shown below:

Device ID = \$31-34.  
Command byte = \$53.  
auxiliary 1 = doesn't matter.  
auxiliary 2 = doesn't matter.  
Checksum = checksum of bytes above.

The diskette controller responds with a data frame of the format shown earlier in this Appendix as part of the STATUS REQUEST discussion.

#### PUT SECTOR (WITH VERIFY)

The computer sends a command frame of the format shown below:

Device ID = \$31-34  
Command byte = \$57.  
auxiliary 1 = low byte of sector number.  
auxiliary 2 = high byte of sector number (1-720).  
Checksum = checksum of bytes above.

The computer sends a data frame of the format shown below:

128 data bytes.  
Checksum byte.

The diskette controller writes the frame data to the specified sector, then reads the sector and compares the content with the frame data. The COMPLETE byte value indicates the status of the operation.

#### PUT SECTOR (NO VERIFY)

The computer sends a command frame of the format shown below:

Device ID = \$31-34  
Command byte = \$50.  
auxiliary 1 = low byte of sector number.  
auxiliary 2 = high byte of sector number (1-720).  
Checksum = checksum of bytes above.

The computer sends a data frame of the format shown below:

128 data bytes.  
Checksum byte.

The diskette controller writes the frame data to the specified sector, then sends a COMPLETE byte value that indicates the status of the operation.

#### GET SECTOR

The computer sends a command frame of the format shown below:

Device ID = \$31-34  
Command byte = \$52.  
auxiliary 1 = low byte of sector number.  
auxiliary 2 = high byte of sector number (1-720).  
Checksum = checksum of bytes above.

The diskette controller sends a data frame of the format shown below:

128 data bytes.  
Checksum byte.

#### FORMAT DISKETTE

The computer sends a command frame of the format shown below:

Device ID = \$31-34  
Command byte = \$21.  
auxiliary 1 = doesn't matter.  
auxiliary 2 = doesn't matter.  
Checksum = checksum of bytes above.

The diskette controller completely formats the diskette (generates 40 tracks of 18 soft sectors per track with the data portion of each sector equal to all zeros) and then reads each sector to verify its integrity. A data frame of 128 bytes plus checksum is returned in that the sector numbers of all bad sectors (up to a maximum of 63 sectors) are contained, followed by two consecutive bytes of \$FF. If there are no bad sectors on the diskette the first 2 bytes of the data

## Appendix L -- OS DATA BASE VARIABLE FUNCTIONAL DESCRIPTIONS

### CENTRAL DATA BASE DESCRIPTION

This appendix provides detailed information for those variables in the OS data base that can be altered by the user. Remaining variables are provided narrative descriptions. Information on the variables is presented in a multiple access scheme: Lookup tables are referenced to a common set of narratives, that is itself ordered by function.

Variable descriptions are referenced by a label called a variable identifier (VID) number. The label comprises a single letter followed by a number. A different letter is assigned for each major functional area being described, and the numbers are assigned sequentially within each functional area. Those variables that are not considered to be of interest to any user are flagged with an asterisk (\*) after their names. The data base lookup tables provided are:

1. Functional grouping -- index to the function narrative and descriptions of variables, giving VID and variable name.
2. Alphabetic list of names -- giving VID of description.
3. Address ordered list -- giving VID of description.

Item 1, the functional grouping index, starts on the next page; the other two lookup tables are at the end of Appendix L.

## FUNCTIONAL INDEX TO DATA BASE VARIABLE DESCRIPTIONS

### A. Memory configuration

- A1 MEMLO
- A2 MEMTOP
- A3 APPMHI
- A4 RAMTOP
- A5 RAMSIZ

### B. Text/graphics screen

#### Cursor control

- B1 CRSINH
- B2 ROWCRS, COLCRS
- B3 OLDROW, OLDCOL
- B4 TXTROW, TXTCOL

#### Screen margins

- B5 LMARGN
- B6 RMARGN

#### Color control

- B7 PCOLRO - PCOLR3
- B8 COLORO - COLOR4

#### Text scrolling

- B9 SCRFLG\*

#### Attract mode

- B10 ATTRACT
- B11 COLRSH\*
- B12 DRKMSK\*

#### Tabbing

- B13 TABMAP

#### Logical text lines

- B14 LOGMAP\*
- B15 LOGCOL\*

#### Split screen

B16 BOTSCR\*

FILL/DRAW function

B17 FILDAT

B18 FILFLG\*

B19 NEW SROW\*, NEWCOL\*

B20 HOLD4\*

B21 ROWINC\*, COLINC\*

B22 DELTAR\*, DELTAC\*

B23 COUNTR\*

B24 ROWAC\*, COLAC\*

B25 ENDPT\*

Displaying control characters

Escape (display following control char)

B26 ESCFLG\*

Display control characters mode

B27 DSPFLG

Bit mapped graphics

B28 DMASK\*

B29 SHFAMT\*

Internal working variables

B30 HOLD1\*  
B31 HOLD2\*  
B32 HOLD3\*  
B33 TMPCHR\*  
B34 DSTAT\*  
B35 DINDEX  
B36 SAVMSC  
B37 OLDCHR\*  
B38 OLDADR\*  
B39 ADRESS\*  
B40 MLTTMP/OPNTMP/TOADR\*  
B41 SAVADR/FRMADR\*  
B42 BUFCNT\*  
B43 BUFSTR\*  
B44 SWPFLG\*  
B45 INSDAT\*  
B46 TMPROW\*, TMPCOL\*  
B47 TMPLBT\*  
B48 SUBTMP\*  
B49 TINDEX\*  
B50 BITMSK\*  
B51 LINBUF\*  
B52 TXTMSC  
B53 TXTOLD\*

Internal character code conversion

B54 ATACHR

B55 CHAR\*

C. Disk Handler

C1 BUFADR\*

C2 DSKTIM\*

D. Cassette (part in SIO part in Handler)

Baud rate determination

D1 CBAUDL\*,CBAUDH\*

D2 TIMFLG\*

D3 TIMER1\*,TIMER2\*

D4 ADDCOR\*

D5 TEMP1\*

D6 TEMP3\*

D7 SAVIO\*

Cassette mode

D8 CASFLG\*

Cassette buffer

D9 CASBUF\*

D10 BLIM\*

D11 BPTR\*

Internal working variables

D12 FEOF\*

D13 FTYPE\*

D14 WMODE\*

D15 FREQ\*

E. Keyboard

Key reading and debouncing

E1 CH1\*

E2 KEYDEL\*

E3 CH

## Special functions

Start/stop  
E4 SSFLAG

[BREAK]  
E5 BRKKEY

[SHIFT]/[CONTROL] lock  
E6 SHFLOK  
E7 HOLDCH\*

Autorepeat  
E8 SRTIMR\*

Inverse video  
E9 INVFLG

Console switches ([SELECT], [START], and [OPTION])

## F. Printer

printer-buffer

F1 PRNBUF\*  
F2 PBUFSZ\*  
F3 PBPNT\*

Internal working variables  
F4 PTEMP\*  
F5 PTIMOT\*

## G. Central I/O routine (CIO)

User call parameters

G1 IOCB  
G2 ICHID  
G3 ICDNO  
G4 ICCOM  
G5 ICSTA  
G6 ICBAL, ICBAH  
G7 ICPTL, ICPTH  
G8 ICBLL, ICBLH  
G9 ICAX1, ICAX2  
G10 ICSPR

Device status  
G11 DVSTAT

device table  
G12 HATABS

## CIO/Handler interface Parameters

G13 ZIOCB (IOCBAS)  
G14 ICHIDZ  
G15 ICDNOZ  
G16 ICCOMZ  
G17 ICSTAZ  
G18 ICBALZ, ICBALH  
G19 ICPTLZ, ICPTHZ  
G20 ICBLLZ, ICBLHZ  
G21 ICAX1Z, ICAX2Z  
G22 ICSPRZ (ICIDNO, CIOCHR)

### Internal working variables

G23 ICCOMT\*  
G24 ICIDNO\*  
G25 CIOCHR\*

## H. Serial I/O routine (SIO)

### User call parameters

H1 DCB control block  
H2 DDEVIC  
H3 DUNIT  
H4 DCOMND  
H5 DSTATS  
H6 DBUFLO, DBUFHI  
H7 DTIMLO  
H8 DBYTLO, DBYTHI  
H9 DAUX1, DAUX2

Bus sound control  
H10 SOUNDR

### Serial bus control

Retry logic  
H11 CRETRY\*  
H12 DRETRY\*

Checksum  
H13 CHKSUM\*  
H14 CHKSNT\*  
H15 NOCKSM\*

## Data buffering

### General buffer control

H16 BUFRLO\*,BUFRHI\*  
H17 BFENLO\*,BFENHI\*

### Command frame output buffer

H18 CDEVIC\*  
H19 CCOMND\*  
H20 CAUX1\*,CAUX2\*

### Receive/transmit data buffering

H21 BUFRFL\*  
H22 RECVDN\*  
H23 TEMP\*  
H24 XMTDON\*

### SIO timeout

H25 TIMFLG\*  
H26 CDTMV1\*  
H27 CDTMA1\*

### Internal working variables

H28 STACKP\*  
H29 TSTAT\*  
H30 ERRFLG\*  
H31 STATUS\*  
H32 SSKCTL\*

## J. ATARI controllers

### Joysticks

J1 STICK0 - STICK3  
J2 STRIGO - STRIG3

### Paddles

J3 PADDLO - PADDL7  
J4 PTRIGO - PTRIG7

### Paddle controllers

J8 STICK0 - STICK3  
J9 STRIGO - STRIG3

## K. Disk file manager

K1 FMSZPG\*  
K2 ZBUFP\*  
K3 ZDRVA\*  
K4 ZSBA\*  
K5 ERRNO\*

L. Disk utilities (DOS)  
L1 DSKUTL\*

M. Floating point package

M1 FRO  
M2 FRE\*  
M3 FR1  
M4 FR2\*  
M5 FRX\*  
M6 EEXP\*  
M7 NSIGN\*  
M8 ESIGN\*  
M9 FCHRFLG\*  
M10 DIGRT\*  
M11 CIX  
M12 INBUFF  
M13 ZTEMP1\*  
M14 ZTEMP4\*  
M15 ZTEMP3\*  
M16 FLPTR  
M17 FPTR2\*  
M18 LBPR1\*  
M19 LBPR2\*  
M20 LBUFF  
M21 PLYARG\*  
M22 FPSCR/FSCR\*  
M23 FPSCR1/FSCR1\*  
M24 DEGFLG/RADFLG\*

N. Power-Up and System Reset

RAM sizing  
N1 RAMLO\*, TRAMSZ\*  
N2 TSTDAT\*

Diskette/cassette-boot

N3 DOSINI  
N4 CKEY\*  
N5 CASSBT\*  
N6 CASINI  
N7 BOOT?\*  
N8 DFLAGS\*  
N9 DBSECT\*  
N10 BOOTAD\*

Environmental control

N11 COLDST  
N12 DOSVEC

[S RESET]  
N13 WARMST

P. Interrupts  
P1 CRITIC  
P2 POKMSK

System Timers

Real-time clock  
P3 RTCLOK

System Timer 1  
P4 CDTMV1  
P5 CDTMA1

System Timer 2  
P6 CDTMV2  
P7 CDTMA2

System Timers 3-5  
P8 CDTMV3, CDTMV4, CDTMV5  
P9 CDTMF3, CDTMF4, CDTMF5

RAM-interrupt vectors

NMI-interrupt vectors  
P10 VDSLST  
P11 VVBLKI  
P12 VVBLKD

IRQ-interrupt vectors  
P13 VIMIRQ  
P14 VPRCED  
P15 VINTER  
P16 VBREAK  
P17 VKEYBD  
P18 VSERIN  
P19 VSEROR  
P20 VSEROC  
P21 VTIMR1, VTIMR2, VTIMR4

Hardware register updates

P22 SDMCTL  
P23 SDLSTL, SDLSTH  
P24 GPRIOR  
P25 CHACT  
P26 CHBAS  
P27 PCOLRx, COLORx

Internal working variable  
P28 INTEMP\*

R. User areas  
R1 (unlabeled)  
R2 USAREA

This appendix contains descriptions of many of the data base variables; descriptions are included for all of the user-accessible variables and for some of the "internal" variables as well. Those variables that are not considered to be normally of interest to any user are flagged with an asterisk (\*) after their names; the other variables can be of interest to one or more of the following classes of users:

- o End user.
- o Game developer.
- o Applications programmer.
- o System utility writer.
- o Language processor developer.
- o Device Handler Writer.

Each variable is specified by its system equate file name followed by its address (in hex) and the number of bytes reserved in the data base (in decimal), in the following form:

<name> [<address>,<size>]

For example:

MEMLO [02E7,2]

Note that most word (2 byte) variables are ordered with the least significant byte at the lower address.

## A. MEMORY CONFIGURATION

See Section 4 for a general discussion of memory dynamics and section 7 for details of system initialization.

A1 MEMLO [02E7,2] -- User-free memory low address

MEMLO contains the address of the first location in the free memory region. The value is established by the OS during power-up and system reset initialization and is never altered by the OS thereafter.

A2 MEMTOP [02E5,2] -- User-free memory high address

MEMTOP contains the address of the first non-useable memory location above the free memory region. The value is established by the OS during power-up and system reset initialization; and then is re-established whenever the display is opened, based upon the requirements of the selected graphics mode.

A3 APPMHI [000E,2] -- User-free memory screen lower limit

APPMHI is a user-controlled variable that contains the address within the free memory region below which the Display Handler cannot go in setting up a display screen. This variable is initialized to zero by the OS at power-up.

A4 RAMTOP\* [006A,1] -- Display Handler top of RAM address (MSB)

RAMTOP permanently retains the RAM top address that was contained in TRAMSZ (as described in N1) for the Display Handler's use. The value is set up as part of Handler initialization.

A5 RAMSIZ [02E4,1] -- Top of RAM address (MSB only)

RAMSIZ permanently retains the RAM top address that was contained in TRAMSZ (as described in N1).

## B. TEXT/GRAPHICS SCREEN

See Section 5 for a discussion of the text and graphics screens and their Handlers.

### Cursor Control

For the text screen and split-screen text window there is a visible cursor on the screen which shows the position of the next input or output operation. The cursor is represented by inverting the video of the character upon which it resides; but the cursor can be made invisible, at the user's option. The graphics screen always has an invisible cursor.

The cursor position is sensed by examining data base variables and can be moved by altering those same variables; in addition, when using the Screen Editor, there are cursor movement control codes that can be sent as data (as explained in Section 5).

B1 CRSINH [02F0,1] -- Cursor display inhibit flag

When CRSINH is zero, all outputs to the text screen will be followed by a visible cursor (inversed character); and when CRSINH is nonzero, no visible cursor will be generated.

CRSINH is set to zero by power-up, the [SYSTEM.RESET] or [BREAK] keys or an OPEN command to the Display Handler or Screen Editor.

Note that altering CRSINH does not cause the visible cursor to change states until the next output to the screen; if an immediate change to the cursor state is desired, without altering the screen data, follow the CRSINH change with the output of CURSOR UP, CURSOR DOWN, or some other innocuous sequence.

B2 ROWCRS [0054,1] and COLCRS [0055,2] -- Current cursor position

ROWCRS and COLCRS define the cursor location (row and column, respectively) for the next data element to be read from or written to the main screen segment. When in split-screen mode, the variables TXTROW and TXTCOL define the cursor for the text window at the bottom of the screen as explained in B4 below.

The row and column numbering start with the value zero, and increase in increments of one to the number of rows or columns minus 1; with the upper left corner of the screen being the origin (0,0).

ROWCRS is a single-byte variable with a maximum allowable value of 191 (screen modes 8-11); COLCRS is a 2-byte variable with a maximum allowable value of 319 (screen mode 8).

B3 OLDROW [005A,1] and OLDCOL [005B,2] -- Prior cursor position

OLDROW and OLDCOL are updated from ROWCRS and COLCRS before every operation. The variables are used only for the DRAW and FILL operations.

B4 TXTROW [0290,1] and TXTCOL [0291,2] -- Split-screen text cursor position

TXTROW and TXTCOL define the cursor location (row and column, respectively) for the next data element to be read from or written to the split-screen text window.

The row and column numbering start with the value zero, and increase in increments of one to 3 and 39, respectively; with the upper left corner of the split-screen text window being the origin (0,0).

#### Screen Margins

The text screen and split-screen text window have user-alterable left and right margins that define the normal domain of the text cursor.

B5 LMARGN [0052,1] -- Text column left margin

LMARGN contains the column number (0-39) of the text screen left margin; the text cursor will remain on or to the right of the left margin as a result of all operations, unless the cursor column variable is directly updated by the user (see B2 and B4 above). The default value for LMARGN is 2 and is established upon power-up or system reset.

B6 RMARGN [0053,1] -- Text column right margin

RMARGN contains the column number (0-39) of the text screen right margin; the text cursor will remain on or to the left of the right margin as a result of all operations, unless the cursor column variable is directly updated by the user (see B2 and B4 above). The default value for RMARGN is 39 and is established upon power-up or system reset.

## Color Control

As part of the stage 2 VBLANK process (see Section 6), the values of nine data base variables are stored in corresponding hardware color control registers. The color registers are divided into two groups: the player/missile colors and the playfield colors. The playfield color registers are utilized by the different screen modes as shown in Appendix H. The player/missile color registers are not used by the standard OS.

### B7 PCOLR0 - PCOLR3 [02C0,4] -- Player/missile graphics colors

Each color variable is stored in the corresponding hardware register as shown below:

|               |               |
|---------------|---------------|
| PCOLR0 [02C0] | COLPM0 [D012] |
| PCOLR1 [02C1] | COLPM1 [D013] |
| PCOLR2 [02C2] | COLPM2 [D014] |
| PCOLR3 [02C3] | COLPM3 [D015] |

Each color variable has the format shown below:

```
 7 6 5 4 3 2 1 0
+---+---+---+---+
| color | lum |x|
+---+---+---+---+
```

See Appendix H for information regarding the color and luminance field values.

### B8 COLOR0 - COLOR4 [02C5,5] -- Playfield colors

Each color variable is stored in the corresponding hardware register as shown below:

|               |               |
|---------------|---------------|
| COLOR0 [02C4] | COLPF0 [D016] |
| COLOR1 [02C5] | COLPF1 [D017] |
| COLOR2 [02C6] | COLPF2 [D018] |
| COLOR3 [02C7] | COLPF3 [D019] |
| COLOR4 [02C8] | COLBK [D01A]  |

Each color variable has the format shown below:

```
 7 6 5 4 3 2 1 0
+---+---+---+---+
| color | lum |x|
+---+---+---+---+
```

See Appendix H for information regarding the color and luminance field values.

## Text Scrolling

The text screen or split-screen text window "scrolls" upward whenever one of the two conditions shown below occurs:

- o A text line at the bottom row of the screen extends past the right margin.
- o A text line at the bottom row of the screen is terminated by an EOL.

Scrolling has the effect of removing the entire logical line that starts at the top of the screen and then moving all subsequent lines upward to fill in the void. The cursor will also move upward if the logical line deleted exceeds one physical line.

B9 SCRFLG\* [02BB,1] -- Scroll flag

SCRFLG is a working variable that counts the number of physical lines minus 1 that were deleted from the top of the screen; since a logical line ranges in size from 1 to 3, SCRFLG ranges from 0 to 2.

## Attract Mode

Attract mode is a mechanism that protects the television screen from having patterns "burned into" the phosphors due to a fixed display being left on the screen for extended periods of time. When the computer is left unattended for more than 9 minutes, the color intensities are limited to 50 percent of maximum and the hues are continually varied every 8.3 seconds. Pressing any keyboard data key will be sufficient to remove the attract mode for 9 more minutes.

As part of the stage 2 VBLANK process, the color registers from the data base are sent to the corresponding hardware color registers; before they are sent, they undergo the following transformation:

hardware register = database variable XOR COLRSH AND DRKMSK

Normally COLRSH = \$00 and DRKMSK = \$FE, thus making the above calculation a null operation; however, once attract mode becomes active, COLRSH = the content of RTCLOK+1 and DRKMSK = \$F6, that has the effect of modifying all of the colors and keeping their luminance always below the 50 percent level.

Since RTCLOK+1 is incremented every 256/60 of a second and since the least significant bit of COLRSH is of no consequence, a

color/lum change will be effected every 8.3 seconds (512/60).

B10 ATTRACT [004D,1] -- Attract mode timer and flag

ATTRACT is the timer (and flag) that controls the initiation and termination of attract mode. Whenever a keyboard key is pressed, the keyboard IRQ service routine sets ATTRACT to zero, thus terminating attract mode; the [BREAK] key logic behaves accordingly. As part of the stage 1 VBLANK process, ATTRACT is incremented every 4 seconds; if the value exceeds 127 (after 9 minutes without keyboard activity), the value of ATTRACT will be set to \$FE and will retain that value until attract mode is terminated.

Since the attract mode is prevented and terminated by the OS based only upon keyboard activity, some users can want to reset ATTRACT based upon Atari-controller event detection, user-controlled Serial I/O bus activity or any other signs of life.

B11 COLRSH\* [004F,1] -- Color shift mask

COLRSH has the value \$00 when attract mode is inactive, thus effecting no change to the screen colors; when attract mode is active, COLRSH contains the current value of the timer variable middle digit (RTCLOCK+1).

B12 DRKMSK\* [004E,1] -- Dark (luminance) mask

DRKMSK has the value \$FE when attract mode is inactive, which does not alter the luminance; and has the value \$F6 when attract mode is active, which forces the most significant bit of the luminance field to zero, thus guaranteeing that the luminance will never exceed 50 percent.

## Tabbing

See Section 5 for a discussion of the use of tabs in conjunction with the Screen Editor.

B13 TABMAP [02A3,15] -- Tab stop setting map

The tab settings are retained in a 15-byte (120 bit) map, where a bit value of 1 indicates a tab setting; the diagram below shows the mapping of the individual bits to tab positions.

| 7   | 6   | 5   | 4   | 3   | 2   | 1   | 0   |          |
|-----|-----|-----|-----|-----|-----|-----|-----|----------|
| +   | +   | +   | +   | +   | +   | +   | +   | +        |
| 0   | 1   | 2   | 3   | 4   | 5   | 6   | 7   | TABMAP+0 |
| +   | +   | +   | +   | +   | +   | +   | +   | +        |
| 8   | 9   | 10  | 11  | 12  | 13  | 14  | 15  | +1       |
| +   | +   | +   | +   | +   | +   | +   | +   | +        |
|     |     |     |     |     |     |     |     |          |
| =   |     |     |     |     |     |     | =   |          |
|     |     |     |     |     |     |     |     |          |
| +   | +   | +   | +   | +   | +   | +   | +   | +        |
| 112 | 113 | 114 | 115 | 116 | 117 | 118 | 119 | +14      |
| +   | +   | +   | +   | +   | +   | +   | +   | +        |

Whenever the Display Handler or Screen Editor is opened, this map is initialized to contain the value of \$01 in every byte, thus providing the default tab stops at 7, 15, 23, etc.

### Logical Text Lines

The text screen is invisibly divided into logical lines of text, each comprising from one to three physical lines of text. The screen is initialized to 24 logical lines of one physical line each; but data entry and/or data insertion can increase the size of a logical line to two or three physical lines.

B14 LOGMAP\* [02B2,4] -- Logical line starting row map

The beginning physical line number for each logical line on the screen is retained in a four byte (32 bit) map, where a bit value of one indicates the start of a logical line; the diagram below shows the mapping of the individual bits to physical line (row) numbers.

| 7  | 6  | 5  | 4  | 3  | 2  | 1  | 0  |          |
|----|----|----|----|----|----|----|----|----------|
| +  | +  | +  | +  | +  | +  | +  | +  | +        |
| 0  | 1  | 2  | 3  | 4  | 5  | 6  | 7  | LOGMAP+0 |
| +  | +  | +  | +  | +  | +  | +  | +  | +        |
| 8  | 9  | 10 | 11 | 12 | 13 | 14 | 15 | +1       |
| +  | +  | +  | +  | +  | +  | +  | +  | +        |
| 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | +2       |
| +  | +  | +  | +  | +  | +  | +  | +  | +        |
|    |    |    |    |    |    |    |    | +3       |
| +  | +  | +  | +  | +  | +  | +  | +  | +        |

The map bits are all set to 1 whenever the text screen is opened or cleared. From that point, the map is updated as logical lines are entered, edited and deleted from the screen.

B15 LOGCOL\* [0063,1] -- Cursor/logical line column number

LOGCOL contains the logical-line column number for the current cursor position; note that a logical line can comprise up to three physical lines. This variable is for the internal use of the Display Handler.

### Split Screen

The Display Handler and Screen Editor together support the operation of a split-screen mode (see Section 5) in which the main portion of the screen is in one of the graphics modes and is controlled by the Display Handler, and there are 4 physical lines in the text window at the bottom of the screen which is controlled by the Screen Editor.

B16 BOTSCR\* [02BF,1] -- Text screen lines count

BOTSCR contains the number of lines of text for the current screen: 24 for mode 0 or 4 for a split-screen mode. The Handler also uses this variable as an indication of the split-screen status; tests are made for the specific values 4 and 24.

### DRAW/FILL Function

The DRAW function line drawing algorithm is shown below translated to the PASCAL language from assembly language.

```
NEWROW := ROWCRS; NEWCOL := COLCRS;

DELTAR := ABS (NEWROW-OLDROW);
ROWINC := SIGN (NEWROW-OLDROW); { +1 or -1 }

DELTAC := ABS (NEWCOL-OLDCOL);
COLINC := SIGN (NEWCOL-OLDCOL); { +1 or -1 }

ROWAC := 0; COLAC := 0;
ROWCRS := OLDROW; COLCRS := OLDCOL;

COUNTR := MAX (DELTAC, DELTAR);
ENDPT := COUNTR;
IF COUNTR = DELTAC
 THEN ROWAC := ENDPT DIV 2
 ELSE COLAC := ENDPT DIV 2;

WHILE COUNTR > 0 DO
 BEGIN
```

```

 ROWAC := ROWAC + DELTAR;
 IF ROWAC >= ENDPT
 THEN
 BEGIN
 ROWAC := ROWAC - ENDPT;
 ROWCRS := ROWCRS + ROWINC
 END;

 COLAC := COLAC + DELTAC;
 IF COLAC >= ENDPT
 THEN
 BEGIN
 COLAC := COLAC - ENDPT;
 COLCRS := COLCRS + COLINC
 END;

 PLOT_POINT; { point defined by ROWCRS and COLCRS }

 IF FILFLG <> 0 THEN FILL_LINE;

 COUNTR := COUNTR - 1

END;

```

The FILL function algorithm (FILL\_LINE above) is described briefly in Section 5.

B17 FILDAT [02FD,1] -- Fill data

FILDAT contains the fill region data value as part of the calling sequence for a FILL command as described in Section 5.

B18 FILFLG\* [02B7,1] -- Fill flag

FILFLG indicates to the shared code within the Display Handler whether the current operation is FILL (FILFLG <> 0) or DRAW (FILFLG = 0).

B19 NEWROW\* [0060,1] and NEWCOL\* [0061,2] -- Destination point

NEWROW and NEWCOL are initialized to the values in ROWCRS and COLCRS, which represent the destination endpoint of the DRAW/FILL command. This is done so that ROWCRS and COLCRS can be altered during the performance of the command.

B20 HOLD4\* [02BC,1] -- Temporary storage

HOLD4 is used to save and restore the value in ATACHR during the FILL process; ATACHR is temporarily set to the value in FILDAT to accomplish the filling portion of the command.

B21 ROWINC\* [0079,1] and COLINC\* [007A,1] -- Row/column increment/decrement

ROWINC and COLINC are the row and column increment values; they are each set to +1 or -1 to control the basic direction of line drawing. ROWINC and COLINC represent the signs of NEWROW - ROWCRS and NEWCOL - COLCRS, respectively.

B22 DELTAR\* [0076,1] and DELTAC\* [0077,2] -- Delta row and delta column

DELTAR and DELTAC contain the absolute values of NEWROW - ROWCRS and NEWCOL - COLCRS, respectively; together with ROWINC and COLINC, they define the slope of the line to be drawn.

B23 COUNTR\* [007E,2] -- Draw iteration count

COUNTR initially contains the larger of DELTAR and DELTAC, that is the number of iterations required to generate the desired line. COUNTR is then decremented after every point on the line is plotted, until it reaches a value of zero.

B24 ROWAC\* [0070,2] and COLAC\* [0072,2] -- Accumulators

ROWAC and COLAC are working accumulators that control the row-and column-point plotting and increment (or decrement) function.

B25 ENDPT\* [0074,2] -- Line length

ENDPT contains the larger of DELTAR and DELTAC, and is used in conjunction with ROWAC/COLAC and DELTAR/DELTAC to control the plotting of line points.

#### Displaying Control Characters

Often it is useful to have ATASCII control codes (such as CLEAR, CURSOR UP, etc). displayed in their graphic forms instead of having them perform their control function. This display capability is provided in two forms when outputting to the Screen Editor: 1) a data content form in which a special character (ESC) precedes each control character to be displayed and 2) a mode control form.

## Escape (Display Following Control Character)

Whenever an ESC character is detected by the Screen Editor, the next character following this code is displayed as data, even if it would normally be treated as a control code; the EOL code is the sole exception. It is always treated as a control code. The sequence ESC ESC will cause the second ESC character to be displayed.

### B26 ESCFLG\* [02A2,1] -- Escape flag

ESCFLG is used by the Screen Editor to control the escape sequence function; the flag is set (to \$80) by the detection of an ESC character (\$1B) in the data stream and is reset (to 0) following the output of the next character.

## Display Control Characters Mode

When it is desired to display ATASCII control codes other than EOL in their graphics form, but not have an ESC character associated with each control code, a display mode can be established by setting a flag in the data base. This capability is used by language processors when displaying high-level language statements, that can contain control codes as data elements.

### B27 DSPFLG [02FE,1] -- Display control characters flag

When DSPFLG is nonzero, ATASCII control codes other than EOL are treated as data and displayed on the screen when output to the Screen Editor. When DSPFLG is zero, ATASCII control codes are processed normally.

DSPFLG is set to zero by Power-up and [SYSTEM.RESET].

## Bit-Mapped Graphics

A number of temporary variables are used by the Display Handler when handling data elements (pixels) going to or from the screen; of interest here are those variables that are used to control the packing and unpacking of graphics data, where a memory byte typically contains more than one data element (for example, screen mode 8 contains 8 pixels per memory byte).

### B28 DMASK\* [02A0,1] -- Pixel location mask

DMASK is a mask that contains zeros for all bits that do not correspond to the specific pixel to be operated upon, and 1's for all bits that do correspond. DMASK can contain the values shown below in binary notation:

```
11111111 -- screen modes 1 and 2; one pixel per byte.

11110000 -- screen modes 9-11; two pixels per byte.
00001111

11000000 -- screen modes 3, 5 and 7; four pixels per byte.
00110000
00001100
00000011

10000000 -- screen modes 4, 6 and 8; eight pixels per byte.
01000000

00000010
00000001
```

B29 SHFAMT\* [006F,1] -- Pixel justification

SHFAMT indicates the amount to shift the right-justified pixel data on output, or the amount to shift the input data to right justify it on input. The value is always the same as for DMASK prior to the justification process.

#### Internal Working Variables

B30 HOLD1\* [0051,1] -- Temporary storage

B31 HOLD2\* [029F,1] -- Temporary storage

B32 HOLD3\* [029D,1] -- Temporary storage

B33 TMPCHR\* [0050,1] -- Temporary storage

B34 DSTAT\* [004C,1] -- Display status

B35 DINDEX [0057,1] -- Display mode

DINDEX contains the current screen mode obtained from the low order four bits of the most recent OPEN AUX1 byte.

B36 SAVMSC [005B,2] -- Screen Memory Address

SAVMSC contains the lowest address of the screen data region; the data at that address is displayed at the upper left corner of the screen.

B37 OLDCHR\* [005D,1] -- Cursor character save/restore

OLDCHR retains the value of the character under the visible text cursor; this variable is used to restore the original character value when the cursor is moved.

B38 OLDADR\* [005E,2] -- Cursor memory address

OLDADR retains the memory address of the current visible text cursor location; this variable is used in conjunction with OLDCHR (B37) to restore the original character value when the cursor is moved.

B39 ADRESS\* [0064,2] -- Temporary storage

B40 MLTTMP/DPNTMP/TOADR\* [0066,2] -- Temporary storage

B41 SAVADR/FRMADR\* [006B,2] -- Temporary storage

B42 BUFCNT\* [006B,1] -- Screen Editor current logical line size

B43 BUFSTR\* [006C,2] -- Temporary storage

B44 SWPFLG\* [007B,1] -- Split-screen cursor control

In split-screen mode, the graphics cursor data and the text window cursor data are frequently swapped as shown below in order to get the variables associated with the region being accessed into the ROWCRS-OLDADR variables.

|            |       |            |
|------------|-------|------------|
| ROWCRS B2  | ----- | TXTRW B4   |
| COLCRS B2  | ----- | TXTCOL B4  |
| DINDEX B35 | ----- | TINDEX B49 |
| SAVMSC B36 | ----- | TXTMSC B52 |
| OLDROW B3  | ----- | TXTOLD B53 |
| OLDCOL B3  | ----- | " "        |
| OLDCHR B37 | ----- | " "        |
| OLDADR B38 | ----- | " "        |

SWPFLG is used to keep track of what data set is currently in the ROWCRS-OLDADR region; SWPFLG is equal to \$FF when split-screen text window cursor data is in the main region, otherwise SWPFLG is equal to 0.

B45 INSDAT\* [007D,1] -- Temporary storage

B46 TMPROW\* [02B8,1] and TMPCOL\* [02B9,2] -- Temporary storage

B47 TMPLBT\* [02A1,1] -- Temporary storage

B48 SUBTMP\* [029E,1] -- Temporary storage

B49 TINDEX\* [0293,1] -- Split screen text window screen mode

TINDEX is the split-screen text window equivalent of DINDEX and is always equal to zero when SWPFLG is equal to zero (see B44).

B50 BITMSK\* [006E,1] -- Temporary storage

B51 LINBUF\* [0247,40] -- Physical line buffer

LINBUF is used to temporarily buffer one physical line of text when the Screen Editor is moving screen data.

B52 TXTMSC [0294,2] -- Split screen memory address

TXTMSC is the split-screen text window version of SAVMSC (B36).

See B44 for more information.

B53 TXTOLD\* [0296,6] -- Split screen cursor data

See B44 for more information.

#### Internal Character Code Conversion

Two variables are used to retain the current character being processed (for both reading and writing); ATACHR contains the value passed to or from CIO, and CHAR contains the internal code corresponding to the value in ATACHR. Because the hardware does not interpret ATASCII characters directly, the transformations shown below are applied to all text data read and written:

| ATASCII<br>CODE | INTERNAL<br>CODE |
|-----------------|------------------|
| 00-1F           | 40-5F            |
| 20-3F           | 00-1F            |
| 40-5F           | 20-3F            |
| 60-7F           | 60-7F            |
| 80-9F           | C0-DF            |

A0-BF  
C0-DF  
E0-FF

80-9F  
A0-BF  
E0-FF

See P26 for more information.

B54 ATACHR [02FB,1] -- Last ATASCII character or plot point

ATACHR contains the ATASCII value for the most recent character read or written, or the value of the graphics point. This variable can also be considered to be a parameter of the FILL/DRAW commands, as the value in ATACHR will determine the line color when a DRAW or FILL is performed.

B55 CHAR\* [02FA,1] -- Internal character code

CHAR contains the internal code value for the most recent character read or written.

#### C. DISKETTE HANDLER

See Section 5 for a discussion of the resident Diskette Handler.

C1 BUFADR\* [0015,2] -- Data buffer pointer

BUFADR acts as temporary page zero pointer to the current diskette buffer.

C2 DSKTIM\* [0246,1] -- Disk format operation timeout time

DSKTIM contains the timeout value for SIO calling sequence variable DTIMLO (see Section 9). DSKTIM is set to 160 (which represents a 171-second timeout) at initialization time, and is updated after each diskette status request operation. It contains the value returned in the third byte of the status frame (see Section 5). Note that all diskette operations other than format have a fixed (7) second timeout, established by the Diskette Handler.

#### D. CASSETTE

See Section 5 for a general description of the Cassette Handler. The cassette uses the Serial I/O bus hardware, but does not conform with the Serial I/O bus protocol as defined in Section 9. Hence, the Serial

I/O utility (SIO) has cassette specific code within it. Some variables in this subsection are utilized by SIO and some by the Cassette Handler.

#### Baud Rate Determination

The input baud rate is assumed to be a nominal 600 baud, but will be adjusted, if necessary, by the SIO routine to account for drive-motor variations, stretched tape, etc. The beginning of every cassette record contains a pattern of alternating 1's and zeros that is used solely for speed correction; by measuring the time to read a fixed number of bits, the true-receive baud rate is determined and the hardware adjusted accordingly. Input baud rates ranging from 318 to 1407 baud can theoretically be handled using this technique.

The input baud rate is adjusted by setting the POKEY counter that controls the bit sampling period.

D1 CBAUDL\* [02EE,1] and CBAUDH\* [02EF,1] -- Cassette baud rate

Initialized to 05CC hex, which represents a nominal 600 baud. After baud rate calculation, these variables will contain POKEY counter values for the corrected baud rate.

D2 TIMFLG\* [0317,1] -- Baud rate determination timeout flag

TIMFLG is used by SIO to timeout an unsuccessful baud rate determination. The flag is initially set to 1, and if it attains a value of zero (after 2 seconds) before the first byte of the cassette record has been read, the operation will be aborted. See also H24.

D3 TIMER1\* [030C,2] and TIMER2\* [0310,2] -- Baud rate timers

These timers contain reference times for the beginning and end of the fixed bit pattern receive period. The first byte of each timer contains the then current vertical line counter value read from ANTIC, and the second byte of each timer contains the then current value of the least significant byte of the OS real time clock (RTCLOCK+2).

The difference between the timers is converted to raster pair counts and is then used to perform a table lookup with interpolation to determine the new values for CBAUDL and CBAUDH.

D4 ADDCOR\* [030E,1] -- Interpolation adjustment variable

ADDCOR is a temporary variable used for the interpolation calculation of the above computation.

D5 TEMP1\* [0312,2] -- Temporary storage

D6 TEMP3\* [0315,1] -- Temporary storage

D7 SAVIO\* [0316,1] -- Serial in data detect

SAVIO is used to retain the state of SKSTAT [D20F] bit 4 (serial data in); it is used to detect (and is updated after) every bit arrival.

#### Cassette Mode

D8 CASFLG\* [030F,1] -- Cassette I/O flag

CASFLG is used internally by SIO to control the program flow through shared code. A value of zero indicates that the current operation is a standard Serial I/O bus operation, and a nonzero value indicates a cassette operation.

#### Cassette Buffer

D9 CASBUF\* [03FD,131] -- Cassette record buffer

CASBUF is the buffer used by the Cassette Handler for the packing and unpacking of cassette-record data, and by the initialization cassette-boot logic. The format for the standard cassette record in the buffer is shown below:

|                     |          |
|---------------------|----------|
| 7 6 5 4 3 2 1 0     |          |
| + + + + + + + + +   |          |
| ! 0 1 0 1 0 1 0 1 ! | CASBUF+0 |
| + + + + + + + + +   |          |
| ! 0 1 0 1 0 1 0 1 ! | +1       |
| + + + + + + + + +   |          |
| ! control byte !    | +2       |
| + + + + + + + + +   |          |
| ! 128 !             | +3       |
| = data =            |          |
| ! bytes !           | +130     |
| + + + + + + + + +   |          |

See Section 5 for an explanation of the standard cassette-record format.

D10 BLIM\* [028A,1] -- Cassette record data size

BLIM contains the count of the number of data bytes in the current cassette record being read. BLIM will have a value ranging from 1 to 128, depending upon the record control byte as explained in Section 5.

D11 BPTR\* [003D,1] -- Cassette-record data index

BPTR contains an index into the data portion of the cassette record being read or written. The value will range from 0 to the then current value of BLIM. When BPTR equals BLIM then the buffer (CASBUF) is full if writing or empty if reading.

#### Internal Working Variables

D12 FEOF\* [003F,1] -- Cassette end-of-file flag

FEOF is used by the Cassette Handler to flag the detection of an end of file condition (control byte = \$FE). FEOF equal to zero indicates that an EOF has not yet been detected, and a nonzero value indicates that an EOF has been detected. The flag is reset at every OPEN.

D13 FTYPE\* [003E,1] -- Interrecord gap type

FTYPE is a copy of ICAX2Z from the OPEN command and indicates the type of interrecord gap selected; a positive value indicates normal record gaps, and a negative value indicates continuous mode gaps.

D14 WMODE\* [0289,1] -- Cassette read/write mode flag

WMODE is used by the Cassette Handler to indicate whether the current operation is a read or write operation; a value of zero indicates read, and a value of \$80 indicates write.

D15 FREQ\* [0040,1] -- Beep count

FREQ is used to retain and count the number of beeps requested of the BEEP routine by the Cassette Handler during the OPEN command process.

## E. KEYBOARD

See Section 5 for a general description of the Keyboard Handler.

### Key Reading and Debouncing

The console key code register is read in response to an IRQ interrupt that is generated whenever a key stroke is detected by the hardware. The key code is compared with the prior key code accepted (CH1); if the codes are not identical, then the new code is accepted and stored in the key code FIFO (CH) and in the prior key code variable (CH1). If the codes are identical, then the new code is accepted only if a suitable key debounce delay has transpired since the prior value was accepted.

If the key code read and accepted is the code for [CTRL] 1, then the display start/stop flag (SSFLAG) is complemented and the value is not stored in the key code FIFO (CH).

In addition to the reading of the key data, SRTIMR is set to \$30 for all interrupts received (see E8), and ATRACT is set to 0 whenever a new code is accepted (see B10).

The Keyboard Handler obtains all key data from CH; whenever a code is extracted from that 1-byte FIFO, the Handler stores a value of \$FF to the FIFO to indicate that the code has been read. See Section 5 for further discussion of the Keyboard Handler's processing of the key codes.

E1 CH1\* [02F2,1] -- Prior keyboard character code.

CH1 contains the key code value of the key most recently read and accepted.

E2 KEYDEL\* [02F1,1] -- Debounce delay timer.

KEYDEL is set to a value of 3 whenever a key code is accepted, and is decremented every 60th of a second by the stage 2 VBLANK process (until it reaches zero).

E3 CH [02FC,1] -- Keyboard character code FIFO.

CH is a 1-byte FIFO that contains either the value of the most recently read and accepted key code or the value \$FF (which indicates that the FIFO is empty). The FIFO is normally read by the Keyboard Handler, but can be read by a user program.

Key data can also be stored into CH by the Autorepeat logic as explained in the discussion relating to E8.

## Special Functions

### Start/Stop

Display Handler and Screen Editor output to the text or graphics mode screen can be stopped and started (without losing any of the output data) through the use of the [CTRL] 1 key combination. Each key depression toggles a flag that is monitored by the above mentioned Handlers. When the flag is nonzero, the handlers wait for it to go to zero before continuing any output.

E4 SSFLAG [02FF,1] -- Start/stop flag

The flag is normally zero, indicating that screen output is not to be stopped. The flag is complemented by every occurrence of the [CTRL] 1 key combination by the keyboard IRQ service routine.

The flag is set to zero upon power-up, [SYSTEM.RESET] or [BREAK] key processing.

### [BREAK] Key

E5 BRKKEY [0011,1] -- [BREAK] key flag

BRKKEY is used to indicate that the [BREAK] key has been pressed. The value is normally nonzero and is set to zero whenever the [BREAK] key is pressed. The code that detects and processes the [BREAK] condition (flag = 0) should set the flag nonzero again.

BRKKEY is monitored by the following OS routines: Keyboard Handler, Display Handler, Screen Editor, Cassette Handler, xx? The detection of a [BREAK] condition during an I/O operation will cause the operation to be aborted and a status of \$80 to be returned to the user.

The flag is set to nonzero upon Power-up, [SYSTEM.RESET] or upon aborting a pending I/O operation.

### [SHIFT]/[CONTROL] Lock

The keyboard control has three different modes for code generation that apply to the alphabetic keys A through Z:  
1) normal, 2) caps lock, and 3) control lock.

In normal mode, all unmodified alphabetic character keys generate the lowercase letter ATASCII code (\$61-7A).

In caps lock mode, all unmodified alphabetic character keys generate the uppercase letter ATASCII code (\$41-5A).

In control lock mode, all unmodified alphabetic character keys generate the control letter ATASCII code (\$01-1A).

In all three modes, any alphabetic character key that is modified (by being pressed in conjunction with the [SHIFT] or [CTRL] key) will generate the desired modified code.

E6 SHFLOK [02BE,1] -- Shift/control lock control flag

SHFLOK normally has one of three values:

- \$00 = normal mode (no locks in effect).
- \$40 = caps lock.
- \$80 = control lock.

SHFLOK is set to \$40 upon Power-up and [SYSTEM.RESET] and is modified thereafter by the OS only when the [CAPS.LOWER] key is pressed (either by itself or in conjunction with the [SHIFT] or [CTRL] key).

E7 HOLDCH\* [007C,1] -- Character holding variable

HOLDCH is used to retain the current character value prior to the [SHIFT]/[CONTROL] logic process.

#### Autorepeat

The Autorepeat feature responds to the continuous depression of a keyboard key by replicating the key code 10 times per second, after an initial 1/2 second delay. The timer variable SRTIMR is used to control both the initial delay and the repeat rate.

Whenever SRTIMR is equal to zero and a key is being held down, the value of the key code is stored in the key code FIFO (CH). This logic is part of the stage 2 VBLANK process.

E8 SRTIMR\* [022B,1] -- Autorepeat timer

SRTIMR is controlled by two independent processes: 1) the keyboard IRQ service routine, which establishes the initial delay value and 2) the stage 2 VBLANK routine that establishes the repeat rate, decrements the timer and implements the auto repeat logic.

## Inverse Video Control

The Keyboard Handler allows the direct generation of more than half of the 256 ATASCII codes; but codes \$80-9A and codes \$A0-FC can be generated only with the "inverse video mode" active. The ATARI key acts as an on/off toggle for this mode, and all characters (except for screen editing control characters) will be subject to inversion when the mode is active.

E9 INVFLG [02B6,1] -- Inverse video flag

INVFLG is normally zero, indicating that normal video ATASCII codes (bit 7 = 0) are to be generated from keystrokes; whenever INVFLG is nonzero, inverse video ATASCII codes (bit 7 = 1) will be generated. The special control codes are exempt from this bit manipulation.

INVFLG is set to zero by power-up and system reset.

The Keyboard Handler inverts bit 7 of INVFLG whenever the ATARI key is pressed; the lower order bits are not altered and are assumed to be zero.

The Keyboard Handler's "exclusive or's" (XOR's) the ATASCII key data with the value in INVFLG at all times; the normal values of \$00 and \$80 thus lead to control of the inverse video bit (bit 7).

Console Keys: [SELECT], [START], and [OPTION]

The console keys are sensed directly from the hardware register CONSOL [D01F]; see the ATARI Home Computer Hardware Manual for details.

## F. PRINTER

See Section 5 for a general description of the Printer Handler.

### Printer-Buffer

F1 PRNBUF\* [03C0,40] -- Printer-record buffer

PRNBUF is the buffer used by the Printer Handler for packing printer data to be sent to the device controller. The buffer is 40 bytes long

and contains nothing but printer data.

#### F2 PBUFSZ\* [001E,1] -- Printer-record size

PBUFSZ contains the size of the Printer-record for the current mode selected; the modes and respective sizes (in decimal bytes) are shown below:

|              |                                            |
|--------------|--------------------------------------------|
| Normal       | 40                                         |
| Double width | 20 (not currently supported by the device) |
| Sideways     | 29                                         |

Status request 4

#### F3 PBPNT\* [001D,1] -- Printer-buffer index

PBPNT contains the current index to the Printer-buffer. PBPNT ranges in value from zero to the value of PBUFSZ.

### Internal Working Variables

#### F4 PTEMP\* [001F,1] -- Printer Handler temporary data save

PTEMP is used by the Printer Handler to temporarily save the value of a character to be output to the printer.

#### F5 PTIMOT\* [001C,1] -- Printer timeout value

PTIMOT contains the timeout value for SIO calling sequence variable DTIMLO (see Section 9); PTIMOT is set to 30 (which represents a 32 second timeout) at initialization time, and is updated after each printer status request operation to contain the value returned in the third byte of the status frame (see Section 5).

### G. CENTRAL I/O ROUTINE (CIO)

See Section 5 for a description of the Central I/O Utility.

### User Call Parameters

CIO call parameters are passed primarily through an I/O Control Block (IOCB); although additional device status information can be returned in DVSTAT, and Handler information is obtained from the device table (HATABS).

#### I/O Control Block

IOCB is the name applied collectively to the 16 bytes associated with each of the 8 provided control structures; see Section 5.

#### G1 IOCB [0340,16] -- I/O Control Block

The label IOCB is the location of the first byte of the first IOCB in the data base. For VIDs G2 through G10, the addresses given are for IOCB #0 only, the addresses for all of the IOCB's are shown below:

|           |         |
|-----------|---------|
| 0340-034F | IOCB #0 |
| 0350-035F | IOCB #1 |
| 0360-036F | IOCB #2 |
| 0370-037F | IOCB #3 |
| 0380-038F | IOCB #4 |
| 0390-039F | IOCB #5 |
| 03A0-03AF | IOCB #6 |
| 03B0-03BF | IOCB #7 |

#### G2 ICHID [0340,1] -- Handler ID

See Section 5. Initialized to \$FF at power-up and system reset.

#### G3 ICDNO [0341,1] -- Device number

See Section 5.

#### G4 ICCDM [0342,1] -- Command byte

See Section 5.

#### G5 ICSTA [0343,1] -- Status

See Section 5.

#### G6 ICBAL,ICBAH [0344,2] -- Buffer address

See Section 5.

G7 ICPTL, ICPTH [0346,2] -- PUT BYTE vector

See Section 5. Initialized to point to CID's "IOCB not OPEN" routine at power-up and system reset.

G8 ICBLL, ICBLH [0348,2] -- Buffer length / byte count

See Section 5.

G9 ICAX1, ICAX2 [034A,2] -- Auxiliary information

See Section 5.

G10 ICSPR [034C,4] -- Spare bytes for Handler use

There is no fixed assignment of these four bytes; the Handler associated with an IOCB can or may not use these bytes.

#### Device Status

G11 DVSTAT [02EA,4] -- Device status

See Section 5 for a discussion of the GET STATUS command.

#### Device Table

G12 HATABS [031A,38] -- Device table

See Section 9 for a description of the device table.

#### CID/Handler Interface Parameters

Communication between CID and a Handler is accomplished using the 6502 machine registers, and a data structure called the Zero-page IOCB (ZIOCB). The ZIOCB is essentially a copy of the particular IOCB being used for the current operation.

## Zero-Page IOCB

### G13 ZIOCB (IOCBAS) [0020,16] -- Zero-page IOCB

The Zero-page IOCB is an exact copy (except as noted in the discussions that follow) of the IOCB specified by the 6502 X register upon entry to CIO; CIO copies the outer level IOCB to the Zero-page IOCB, performs the indicated function, moves the (possibly altered) Zero-page IOCB back to the outer level IOCB, and then returns to the caller.

Although both the outer level IOCB and the Zero-page IOCB are defined to be 16 bytes in size, only the first 12 bytes are moved by CIO.

### G14 ICHIDZ [0020,1] -- Handler index number

See Section 5. Set to \$FF on CLOSE.

### G15 ICDNOZ [0021,1] -- Device drive number

See Section 5.

### G16 ICCOMZ [0022,1] -- Command byte

See Section 5.

### G17 ICSTAZ [0023,1] -- Status byte

See Section 5.

### G18 ICBALZ, ICBALH [0024,2] -- Buffer address

See Section 5. This pointer variable is modified by CIO in the course of processing some commands; however, the original value is restored before returning to the caller.

### G19 ICPTLZ, ICPTHZ

See Section 5. Set to point to CIO's "IOCB not OPEN" routine on CLOSE.

### G20 ICBLLZ, ICBLHZ [0028,2] -- Buffer length / byte count

See Section 5. This double-byte variable, which starts out representing the buffer length, is modified by CIO in the course

of processing some commands; then, before returning to the caller, the transaction byte count is stored therein.

G21 ICAX1Z, ICAX2Z [002A, 2] -- Auxiliary information

See Section 5.

G22 ICSPRZ (ICIDNO, CIOCHR) [002C, 4] -- CIO working variables

ICSPRZ and ICSPRZ+1 are used by CIO in obtaining the appropriate Handler entry point from the handler's vector table (see Section 9).

ICSPRZ+2 is also labeled ICIDNO and retains the value of the 6502 X register from CIO entry. The X register is loaded from ICIDNO as CIO returns to the caller.

ICSPRZ+3 is also labeled CIOCHR and retains the value of the 6502 A register from CIO entry, except for data reading type commands, in which case the most recent data byte read is stored in CIOCHR. The 6502 A register is loaded from CIOCHR as CIO returns to the caller.

#### Internal Working Variables

G23 ICCOMT\* [0017, 1] -- Command table index

ICCOMT is used as an index to CIO's internal command table, which maps command byte values to Handler entry offsets (see Section 9 for more information). ICCOMT contains the value from ICCOMZ except when ICCOMZ is greater than \$0E, in which case ICCOMT is set to \$0E.

G24 ICIDNO\* [002E, 1] -- CIO call X register save/restore

See G22.

G25 CIOCHR\* [002F, 1] -- CIO call A register save/restore

See G22.

#### H. SERIAL I/O ROUTINE (SIO)

See Section 9 for discussions relating to SIO.

## User Call Parameters

SIO call parameters are passed primarily through a Device Control Block; although an additional "noisy bus" option exists that is selectable through a separate variable.

### Device Control Block

H1 DCB [0300,12] -- Device Control Block

DCB is the name applied collectively to the 12 bytes at locations 0300-030B. These bytes provide the parameter passing mechanism for SIO and are described individually below.

H2 DDEVIC [0300,1] -- Device bus ID

See Section 9.

H3 DUNIT [0301,1] -- Device unit number

See Section 9.

H4 DCOMND [0302,1] -- Device command

See Section 9.

H5 DSTATS [0303,1] -- Device status

See Section 9.

H6 DBUFLO,DBUFHI [0304,2] -- Handler buffer address

See Section 9.

H7 DTIMLO [0306,1] -- Device timeout

See Section 9.

H8 DBYTLO,DBYTHI [0308,2] -- Buffer length / byte count

See Section 9.

H9 DAUX1, DAUX2 [030A, 2] -- Auxiliary information

See Section 9.

#### Bus Sound Control

H10 SOUND [0041, 1] -- Quiet/noisy I/O flag

SOUND is a flag used to indicate to SIO whether noise is to be generated on the television audio circuit when Serial I/O bus activity is in progress. SOUND equal to zero indicates that sound is to be inhibited, and nonzero indicates that sound is to be enabled. SIO sets SOUND to 3 at power-up and system reset.

#### Serial Bus Control

##### Retry Logic

SIO will attempt one complete command retry if the first attempt is not error free, where a complete command try consists of up to 14 attempts to send (and acknowledge) a command frame, followed by a single attempt to receive COMPLETE and possibly a data frame.

H11 CRETRY\* [0036, 1] -- Command frame retry counter

CRETRY controls the inner loop of the retry logic, that associated with sending and receiving an acknowledgement of the command frame. CRETRY is set to 13 by SIO at the beginning of every command initiation, thus allowing for an initial attempt and up to 13 additional retries.

H12 DRETRY\* [0037, 1] -- Device retry counter

DRETRY controls the outer loop of the retry logic, that associated with initiating a command retry after a failure subsequent to the command frame acknowledgement. DRETRY is set to 1 by SIO at entry, thus allowing for an initial attempt and 1 additional retry.

## Checksum

The Serial I/O bus protocol specifies that all command and data frames must contain a checksum validation byte; this byte is the arithmetic sum (with end-around carry) of all of the other bytes in the frame.

H13 CHKSUM\* [0031,1] -- Checksum value

CHKSUM contains the frame checksum as computed by SIO for all frame transfers.

H14 CHKSNT\* [003B,1] -- Checksum sent flag

CHKSNT indicates to the serial bus transmit interrupt service routine whether the frame checksum byte has been sent yet. CHKSNT equal to zero indicates that the checksum byte has not yet been sent; after the checksum is sent, CHKSNT is then set nonzero.

H15 NOCKSM\* [003C,1] -- No checksum follows data flag

NOCKSM is a flag used to communicate between the SIO top level code and the Serial bus receive interrupt service routine that the next input will not be followed by a checksum byte. A value of zero specifies that a checksum byte will follow, nonzero specifies that a checksum byte will not follow.

## Data Buffering

### General Buffer Control

H16 BUFRLO\* [0032,1] and BUFRHI\* [0033,1] -- Next byte address

BUFRLO and BUFRHI comprise a pointer to the next buffer location to be read from or written to. For a data frame transfer, the pointer is initially set to the value contained in the SIO call parameters DBUFLO and DBUFHI, and is then incremented by the interrupt service routines as a part of normal bus data transfer. For a command frame transfer, the pointer is set to point to the SIO-maintained command frame output buffer.

H17 BFENLO\* [0034,1] and BFENHI\* [0035,1] -- Buffer end address

BFENLO/BFENHI form a pointer to the byte following the last frame data byte (not including the checksum) to be sent or received.

BFENLO/BFENHI is the arithmetic sum of BUFRLO/BUFRHI plus the frame size plus -1.

#### Command Frame Output Buffer

See Section 9 for the command frame format and description.

H18 CDEVIC\* [023A,1] -- Command frame device ID

CDEVIC is set to the value obtained by adding SIO call parameter DDEVIC to DUNIT and subtracting 1.

H19 CCOMND\* [023B,1] -- Command frame command.

CCOMND is set to the value obtained from SIO call parameter DCOMND.

H20 CAUX1\* [023C,1] and CAUX2\* [023D,1] -- Auxiliary information

CAUX1 and CAUX2 are set to the values obtained from SIO call parameters DAUX1 and DAUX2, respectively.

#### Receive/Transmit Data Buffering

H21 BUFRFL\* [003B,1] -- Buffer full flag

BUFRFL is a flag used by the serial bus receive interrupt service routine to indicate when the main portion of a bus frame has been received -- all but the checksum byte. BUFRFL equal to zero indicates that the main portion has not been completely received, a nonzero value indicates that the main portion has been received.

H22 RECVDN\* [0039,1] -- Receive frame done flag

RECVDN is a flag used by SIO to communicate between the Serial bus receive interrupt service routine and the main SIO code. The flag is initially set to zero by SIO, and later set nonzero by the interrupt service routine after the last byte of a bus frame has been received.

H23 TEMP\* [023E,1] -- SIO 1-byte I/O data

TEMP is used to receive 1-byte responses from serial bus controllers, such as ACK, NAK, COMPLETE or ERROR.

H24 XMTDON\* [003A,1] -- Transmit frame done flag

XMTDON is a flag used by SIO to communicate between the Serial bus transmit interrupt service routine and the main SIO code. The flag is initially set to zero by SIO, and later set nonzero by the interrupt service routine after the last byte of a bus frame has been transmitted.

#### SIO Timeout

SIO uses System Timer 1 to provide the timeout capability for various operations initiated internally. See Section 6 for a discussion of the capabilities of the System Timers. TIMFLG is the flag used to communicate between SIO and the timer initiated code pointed to by CDTMA1.

H25 TIMFLG\* [0317,1] -- SIO operation timeout flag

TIMFLG is used to indicate a timeout situation for a bus operation. The flag is initially set to 1, and if it attains a value of zero (after the timeout period) before the current operation is complete, the operation will be aborted. See also D2.

H26 CDTMV1\* [0218,2] -- System Timer 1 value

This 2-byte count takes on various values depending upon the operation being timed. See also P4.

H27 CDTMA1\* [0226,2] -- System Timer 1 address

This vector always points to the JTIMER routine, whose only function is to set TIMFLG to zero. This vector is initialized by SIO before every use, so that System Timer 1 can be used by any process that does not use SIO within a timing function. See also P5.

## Internal Working Variables

H28 STACKP\* [0318,1] -- Stack pointer save/restore

STACKP contains the value of the 6502 SP register at entry to SIO; this is retained to facilitate a direct error exit from an SIO subroutine.

H29 TSTAT\* [0319,1] -- Temporary status

TSTAT is used to return the operation status from the WAIT routine and will contain one of the SIO status byte values as shown in Appendix B.

H30 ERRFLG\* [023F,1] -- I/O error flag

ERRFLG is used for communication between the WAIT routine and the outer level SIO code. ERRFLG is normally zero, but is set to \$FF when a device responds with an invalid response byte.

H31 STATUS\* [0030,1] -- SIO operation status

STATUS is a zero-page variable that is used within SIO to contain the operation status that will be stored to the calling sequence parameter variable DSTATS when SIO returns to the caller.

H32 SSKCTL\* [0232,1] -- SKCTL copy

SSKCTL is utilized by SIO to keep track of the content of the SKCTL [D20F] register, which is a write-only register.

## J. ATARI CONTROLLERS

The ATARI controllers are read as part of the Stage 2 VBLANK process. The encoded data is partially decoded and processed as shown in the subsections that follow.

### Joysticks

Up to four joystick controllers can be attached to the computer console, each with a 9-position joystick plus a trigger button.

J1 STICK0 - STICK3 [0278,4] -- Joystick position sense

The 4 joystick position sense variables contain a bit-encoded position sense as shown below:

```
 7 6 5 4 3 2 1 0
+--+--+--+--+--+--+
!0 0 0 0!R!L!D!U!
+--+--+--+--+--+--+
```

where: R = 0 indicates joystick RIGHT sensor true.  
L = 0 indicates joystick LEFT sensor true.  
D = 0 indicates joystick DOWN sensor true.  
U = 0 indicates joystick UP sensor true.

Nine unique combinations are possible, indicating the possible joystick positions shown below:

|            |      |
|------------|------|
| CENTER     | \$0F |
| UP         | \$0E |
| UP/RIGHT   | \$06 |
| RIGHT      | \$07 |
| DOWN/RIGHT | \$05 |
| DOWN       | \$0D |
| DOWN/LEFT  | \$09 |
| LEFT       | \$0B |
| UP/LEFT    | \$0A |

J2 STRIG0 - STRIG3 [0284,4] -- Joystick trigger sense

The four joystick trigger sense variables each contain a single bit indicating the position of the joystick trigger as shown below:

```
 7 6 5 4 3 2 1 0
+--+--+--+--+--+--+
!0 0 0 0 0 0 0!T!
+--+--+--+--+--+--+
```

where: T = 0 indicates trigger pressed.

## Paddles

Up to eight paddle controllers can be connected to the computer, each with a potentiometer and a trigger sense.

J3 PADDL0 - PADDL7 [0270,8] -- Paddle position sense

There is a single-byte variable associated with each paddle position sense; the values range from 228 for full

counterclockwise rotation to 1 for full clockwise rotation.

The paddle values are often converted by the user, as shown below, to give a result of 0 for full counterclockwise rotation and 227 for full clockwise rotation:

```
VALUE := 228 - PADDLX;
```

J4 PTRIGO - PTRIG7 [027C,8] -- Paddle trigger sense

The 8-paddle trigger sense variables each contain a single bit indicating the position of the paddle trigger as shown below:

```
 7 6 5 4 3 2 1 0
+---+---+---+---+
!0 0 0 0 0 0 0!T!
+---+---+---+---+
```

where: T = 0 indicates trigger pressed.

#### Light Pen

The OS reads the position of a single light pen and stores the horizontal and vertical position codes in two variables; these codes are not the same as the actual screen coordinates. The pen position codes for different portions of the screen are shown below:

Left edge -- 67.

Codes increase in increments of one to a value of 227, then go to 0 and continue to increase monotonically (one count per color clock).

Right edge -- 7.

Upper edge -- 16.

Codes increase in increments of one (one count per two raster lines). Lower edge -- 111.

The light pen hardware will read and latch the pen position 60 times per second, independent of the pen button position, which is separately sensed.

In order for the light pen to operate it must be positioned over a portion of the screen which has sufficient luminance to activate the photosensor in the pen; a blank (dark) screen will generally not provide enough luminance to utilize the light pen.

J5 LPENH [0234,1] -- Light pen horizontal position code

LPENH contains the horizontal position code for the light pen; the algorithm below (written in Pascal) shows the conversion from position code to screen coordinate (screen mode 7):

```
IF LPENH < 33 { check for rollover point }
THEN { adjust values to right of rollover }
```

```

 XPOS := LPENH + 227
 ELSE { no adjustment to left of rollover point }
 XPOS := LPENH;
 XPOS := XPOS - 67; { adjust for left edge offset }
 IF XPOS < 0 THEN XPOS := 0;
 IF XPOS > 159 THEN XPOS := 159;

```

J6 LPENV [0235, 1] -- Light pen vertical position code

LPENV contains the vertical position code for the light pen; the algorithm below (written in Pascal) shows the conversion from position code to screen coordinate (screen mode 7):

```

YPOS := LPENV - 16; { adjust for upper edge offset }
IF YPOS < 0 THEN YPOS := 0;
IF YPOS > 95 THEN YPOS := 95;

```

J7 STICK0 - STICK3 [0278, 4] -- Light pen button sense

The light pen button sense is encoded in one of STICK0 - STICK3 (depending upon the actual controller port used) as shown below:

```

 7 0
+---+---+---+---+---+
| 1010101T|
+---+---+---+---+---+

```

where: T = 0 indicates the light pen button is pressed.

## Driving Controllers

The driving controller has no position stops and thus allows unlimited rotation in either direction; the output of the controller is a 2-bit Gray code which can be used to determine the direction of rotation. The controller is sensed using the same internal hardware as the joystick, thus the same data base variables are used for both.

J8 STICK0 - STICK3 [0278,4] -- Driving controller sense

The 4 driving controller sense variables contain an encoded rotation (position) sense value, as shown below:

```
 7 6 5 4 3 2 1 0
+---+---+---+---+
!0 0 0 0 1 1!val!
+---+---+---+---+
```

where a clockwise rotation of the controller produces the following continuous sequence of four values (shown in hexadecimal):

0F, 0D, 0C, 0E, 0F, 0D, .....

and a counterclockwise rotation of the controller produces the following continuous sequence of four values:

0F, 0E, 0C, 0D, 0F, 0E, .....

J9 STRIG0 - STRIG3 [0284,4] -- Driving trigger sense

The four driving trigger sense variables each contain a single bit indicating the position of the driving trigger as shown below:

```
 7 6 5 4 3 2 1 0
+---+---+---+---+
!0 0 0 0 0 0 0!T!
+---+---+---+---+
```

where: T = 0 indicates trigger pressed.

## K. DISK FILE MANAGER

See Section 5 for information relating to the Disk File Manager.

K1 FMSZPG\* [0043,7] -- FMS reserved space

FMSZPG is the reserved space in the database for the variables shown below; the names associated with K2 through K5 are not in the system equate file.

K2 ZBUFP\* [0043,2] -- Buffer pointer

K3 ZDRVA\* [0045,2] -- Drive pointer

K4 ZSBA\* [0047,2] -- Sector buffer pointer

K5 ERRNO\* [0049,1] -- Error number

#### L. DISK UTILITY POINTER

L1 DSKUTL\* [001A,2] -- Page-zero pointer variable

#### M. FLOATING POINT PACKAGE

See Section 8 for a description of the Floating Point Package.

M1 FRO [00D4,6] -- FP register 0

M2 FRE\* [00DA,6] -- FP register (internal)

M3 FR1 [00E0,6] -- FP register 1

M4 FR2\* [00E6,6] -- FP register 2 (internal)

M5 FRX\* [00EC,1] -- Spare (unused)

M6 EEXP\* [00ED,1] -- Exponent value (internal)

M7 NSIGN\* [00EE,1] -- Sign of mantissa (internal)

M8 ESIGN\* [00EF,1] -- Sign of exponent (internal)

M9 FCHRFLG\* [00F0,1] -- First character flag (internal)

M10 DIGRT\* [00F1,1] -- Digits to right of decimal point

M11 CIX [00F2,1] -- Character index

M12 INBUFF [00F3,2] -- Input text buffer pointer

M13 ZTEMP1\* [00F5,2] -- Temporary storage  
 M14 ZTEMP4\* [00F7,2] -- Temporary storage  
 M15 ZTEMP3\* [00F9,2] -- Temporary storage  
 M16 FLPTR [00FC,2] -- Pointer to FP number  
 M17 FPTR2\* [00FE,2] -- FP package use  
 M18 LBPR1\* [057E,1] -- LBUFF preamble  
 M19 LBPR2\* [057F,1] -- LBUFF preamble  
 M20 LBUFF [0580,96] -- Text buffer  
 M21 PLYARG\* [05E0,6] -- FP register (internal)  
 M22 FPSCR/FSCR\* [05E6,6] -- FP register (internal)  
 M23 FPSCR1/SCR1\* [05EC,6] -- FP register (internal)  
 M24 DEGFLG/RADFLG [00FB,1] -- Degrees/radians flag

DEGFLG = 0 indicates radians, 6 indicates degrees.

#### N. Power-Up and SYSTEM RESET

See Section 7 for details of the power-up and system reset operations.

#### RAM Sizing

During power-up and system reset the first non-RAM address above 1000 hex is located and its address retained using a nondestructive test. The first byte of every 4K memory "block" is tested to see if it is alterable; if so, the original value is restored and the next block is tested, and if not, that address is considered to be the end of RAM.

N1 RAMLO\*/TRAMSZ\* [0004,3] -- RAM data/test pointer (temporary)

RAMLO+1 contains the LSB of the address to be tested (always = 0) and TRAMSZ (same as RAMLO+2) contains the MSB of the address to be tested. RAMLO+0 contains the complemented value of the data originally contained in the memory location being tested.

Later in the initialization process these variables are used for totally unrelated functions; but first the value in TRAMSZ is moved to the variables RAMSIZ and MEMTOP+1.

N2 TSTDAT\* [0007,1] -- Test data byte save

TSTDAT contains the original value of the memory location being tested.

#### Diskette/Cassette-Boot

As a part of the Power-up sequence, software can be booted from an attached disk drive or cassette player as explained in Section 10.

N3 DOSINI [000C,2] -- Diskette-boot initialization vector.

DOSINI contains the disk booted software initialization address from the beginning of the boot file (see Section 10) whenever a diskette-boot is successfully completed.

N4 CKEY\* [004A,1] -- Cassette-boot request flag

CKEY is an internal flag used to indicate that the console [START] key was pressed during Power-up, thus indicating that a cassette-boot is desired. CKEY equals zero when no cassette-boot is requested, and is nonzero when a cassette-boot is requested. The flag is cleared to zero after a cassette-boot.

N5 CASSBT\* [004B,1] -- Cassette-booting flag

CASSBT is used during the cassette-boot process to indicate to shared code that the cassette is being booted and not the diskette. CASSBT equal to zero indicates a diskette-boot, and nonzero indicates a cassette-boot.

N6 CASINI [0002,2] -- Cassette-boot initialization vector

CASINI contains the cassette-booted software initialization address from the beginning of the boot file (see Section 10) whenever a

cassette-boot is successfully completed.

N7 BOOT?\* [0009,1] -- Successful diskette/cassette-boot flag.

BOOT? indicates to the initialization processor which, if any, of the boot operations went to successful completion. The flag values are set by the OS and the format for the variable is shown below:

```

 7 6 5 4 3 2 1 0
+---+---+---+---+
| |C|D|
+---+---+---+---+
```

where: C = 1 indicates that the cassette-boot was completed.

D = 1 indicates that the diskette-boot was completed.

N8 DFLAGS\* [0240,1] -- Diskette flags

DFLAGS contains the value of the first byte of the boot file, after a diskette-boot. See Section 10.

N9 DBSECT\* [0241,1] -- Diskette-boot sector count

DBSECT is initially set to the value of the second byte of the boot file, during a diskette-boot, and is then used to control the number of additional diskette sectors read, if any.

N10 BOOTAD\* [0242,2] -- Diskette-boot memory address

BOOTAD is initially set to the value of the third and fourth bytes of the boot file, during a diskette-boot, and is not modified thereafter.

#### Environment Control

If, at the end of a power-up or system reset, control is not given to one of the cartridges (as explained in Sections 7 and 10), then program control passes to the address contained in the data base variable DOSVEC.

N11 COLDST\* [0244,1] -- Coldstart complete flag

COLDST is used by the initialization routine to detect the case of a system reset occurring before the completion of the power-up process. COLDST is set to \$FF at the beginning of the power-up

sequence and is set to 0 at the completion; if a system reset occurs while the value is nonzero, the power-up sequence will be reinitiated (rather than initiating a system reset sequence).

N12 DOSVEC [000A,2] -- Noncartridge control vector

At the beginning of power-up the OS sets DOSVEC to point to the "blackboard" routine; DOSVEC can then be altered as a consequence of a diskette-boot or cassette-boot (as explained in Section 10) to establish a new control program. Control will be passed through DOSVEC on all power-up and system reset conditions in which a cartridge does not take control first.

### System Reset

N13 WARMST [0008,1] -- Warmstart flag

WARMST equals \$FF during a system reset (warmstart) initialization and equals 0 during a power-up initialization (coldstart).

## P. INTERRUPTS

See Section 6 for a discussion of interrupt processing.

P1 CRITIC [0042,1] -- Critical code section flag

CRITIC is used to signal to the VBLANK interrupt processor that a critical code section is executing without IRQ interrupts being inhibited; the VBLANK interrupt processor will stop interrupt processing after stage 1 and before stage 2, just as if the 6502 processor I bit were set, when CRITIC is set.

CRITIC equal to zero indicates that the currently executing code section is noncritical, while any nonzero value indicates that the currently executing code section is critical.

P2 POKMSK [0010,1] -- POKEY interrupt mask

POKMSK is a software maintained interrupt mask that is used in conjunction with the enabling and disabling of the various POKEY interrupts. This mask is required because the POKEY interrupt enable register IRGEN [D20E] is a write-only register, and at any point in time the system can have several users independently enabling and disabling POKEY interrupts. POKMSK is updated by the

users to always contain the current content of IRGEN.

## System Timers

The System Timers are discussed in detail in Section 6.

### Realtime Clock

The realtime clock (or frame counter, as it is sometimes called) is incremented as part of the stage 1 VBLANK process as explained in Section 6.

P3 RTCLOK [0012,3] -- Realtime frame counter

RTCLOK+0 is the most significant byte, RTCLOK+1 the next most significant byte, and RTCLOK+2 the least significant byte. See the discussions at D3 and preceding B10 for OS use of RTCLOK.

### System Timer 1

System Timer 1 is maintained as part of the stage 1 VBLANK process, and thus has the highest priority of any of the user timers.

P4 CDTMV1 [0218,2] -- System Timer 1 value

CDTMV1 contains zero when the timer is inactive, otherwise it contains the number of VBLANKs remaining until timeout. Also see H26.

P5 CDTMA1 [0226,2] -- System Timer 1 jump address

CDTMA1 contains the address to which to JSR should the timer timeout. See also H27 and Section 6.

## System Timer 2

System Timer 2 is maintained as part of the stage 2 VBLANK process, and has the second highest priority of the user timers. The OS does not have any direct use for System Timer 2.

P6 CDTMV2 [021A,2] -- System Timer 2 value

CDTMV2 contains zero when the timer is inactive, otherwise it contains the number of VBLANKs remaining until timeout.

P7 CDTMA2 [0228,2] -- System Timer 2 jump address

CDTMA2 contains the address to which to JSR should the timer timeout. See Section 6.

## System Timers 3, 4 and 5

System Timers 3, 4 and 5 are maintained as part of the stage 2 VBLANK process, and have the lowest priority of the user timers. The OS does not have any direct use for these timers.

P8 CDTMV3 [021C,2], CDTMV4 [021E,2] and CDTMV5 [0220,2]

These variables contain zero when the corresponding timers are inactive, otherwise they contain the number of VBLANKs remaining until timeout.

P9 CDTMF3 [022A,1], CDTMF4 [022C,1] and CDTMF5 [022E,2]

Each of these 1-byte variables will be set to zero should its corresponding timer timeout. The OS never modifies these bytes except to set them to zero upon timeout (and initialization).

## RAM Interrupt Vectors

There are RAM vectors for many of the interrupt conditions within the system. See Section 6 for a discussion of the placing of values to these vectors.

## NMI Interrupt Vectors

P10 VDSLST [0200,2] -- Display-list interrupt vector

This vector is not used by the OS. See Section 6.

P11 VVBLKI [0222,2] -- Immediate VBLANK vector

This vector is initialized to point to the OS stage 1 VBLANK

P12 VVBLKD [0224,2] -- Deferred VBLANK vector

This vector is initialized to point to the OS VBLANK exit routine. See Section 6.

## IRQ Interrupt Vectors

P13 VIMIRQ [0216,2] -- General IRQ vector

This vector is initialized to point to the OS IRQ interrupt processor. See Section 6.

P14 VPRCED [0202,2] -- Serial I/O bus proceed signal

The serial bus line that produces this interrupt is not used in the current system. See Section 6.

P15 VINTER [0204,2] -- Serial I/O bus interrupt signal

The serial bus line that produces this interrupt is not used in the current system. See Section 6.

P16 V[BREAK] [0206,2] -- BRK instruction vector

This vector is initialized to point to a PLA, RTI sequence as the OS proper does not utilize the BRK instruction. See Section 6.

P17 VKEYBD [0208,2] -- Keyboard interrupt vector

This vector is initialized to point to the Keyboard Handler's interrupt service routine. See Section 6 and the discussion preceding E1.

P18 VSERIN [020A,2] -- Serial I/O bus receive data ready

This vector is initialized to point to the SIO utility's interrupt service routine. See Section 6.

P19 VSEROR [020C,2] -- Serial I/O bus transmit ready

This vector is initialized to point to the SIO utility's interrupt service routine. See Section 6.

P20 VSEROC [020E,2] -- Serial I/O bus transmit complete

This vector is initialized to point to the SIO utility's interrupt service routine. See Section 6.

P21 VTIMR1 [0210,2], VTIMR2 [0212,2] and VTIMR4 [0214,2] -- POKEY timer vectors

The POKEY timer interrupts are not used by the OS See Section 6.

#### Hardware Register Updates

As part of the stage 2 VBLANK process, certain hardware registers are updated from OS data base variables as explained in Section 6.

P22 SDMCTL\* [022F,1] -- DMA control

SDMCTL is set to a value of \$02 at the beginning of a Display Handler OPEN command, and then later set to a value of \$22. The value of SDMCTL is stored to DMACTL [D400] as part of the stage 2 VBLANK process.

P23 SDLSTL\* [0230,1] and SDLSTH\* [0231,1] -- Display list address

The Display Handler formats a new display list with every OPEN command and puts the display list address in SDLSTL and SDLSTH. The value of these bytes are stored to DLISTL [D402] and DLISTH [D403] as part of the stage 2 VBLANK process.

|           |         |
|-----------|---------|
| 0360-036F | IOCB #2 |
| 0370-037F | IOCB #3 |
| 0380-038F | IOCB #4 |
| 0390-039F | IOCB #5 |
| 03A0-03AF | IOCB #6 |
| 03B0-03BF | IOCB #7 |

NOTE: There is a potential timing problem associated with the updating of the hardware registers from the data base variables. Since the stage 2 VBLANK process is performed with interrupts enabled, it is possible for an IRQ interrupt to occur before the updating of DLISTH and DLISTL. If the processing of that interrupt (plus other nested interrupts) exceeds the vertical-blank delay (1 msec), then the display list pointer register will not have been updated when display list processing commences for the new frame, and a screen glitch will result.

P24 GPRIOR\* [026F,1] -- Priority control

The Display Handler alters bits 6 and 7 of GPRIOR as part of establishing the GTIA mode. The value of GPRIOR is stored to PRIOR [D01B] as part of the stage 2 VBLANK process.

P25 CHACT\* [02F3,1] -- Character control

The Display Handler sets CHACT to \$02 on every OPEN command. The value of CHACT is stored to CHACTL [D401] as part of the stage 2 VBLANK process.

P26 CHBAS [02F4,1] -- Character address base

The Display Handler sets CHBAS to \$E0 on every OPEN command. The value of CHBAS is stored to CHBASE [D409] as part of the stage 2 VBLANK process. This variable controls the character subset for screen modes 1 and 2; a value of \$E0 provides the capital letters and number set whereas a value of \$E2 provides the lowercase letters and special graphics set. See B55 for more information.

P27 PCOLRx [02C0,4] and COLORx [02C4,5] -- Color registers

See B7 and B8.

#### Internal Working Variables

P28 INTEMP\* [022D,1] -- Temporary storage

INTEMP is used by the SETVBL (SETVBV) routine.

## R. USER AREAS

The areas shown below are available to the user in a non-nested environment. See Section 4 for further information.

R1 [0080, 128]

R2 [0480, 640]

## ALPHABETICAL LIST OF DATA BASE VARIABLES

| NAME    | VID     | ADDRESS SIZE |
|---------|---------|--------------|
| ADDCOR  | D4      | 030E, 1      |
| ADRESS  | B39     | 0064, 2      |
| APPMHI  | A3      | 000E, 2      |
| ATACHR  | B54     | 02FB, 1      |
| ATTRACT | B10     | 004D, 1      |
| BFENHI  | H17     | 0035, 1      |
| BFENLO  | H17     | 0034, 1      |
| BITMSK  | B50     | 006E, 1      |
| BLIM    | D10     | 028A, 1      |
| BOOT?   | N7      | 0009, 1      |
| BOOTAD  | N10     | 0242, 2      |
| BOTSCR  | B16     | 02BF, 1      |
| BPTR    | D11     | 003D, 1      |
| BRKKEY  | E5      | 0011, 1      |
| BUFADR  | C1      | 0015, 2      |
| BUFCNT  | B42     | 006B, 1      |
| BUFRFL  | H21     | 0038, 1      |
| BUFRHI  | H16     | 0033, 1      |
| BUFRLO  | H16     | 0032, 1      |
| BUFSTR  | B43     | 006C, 2      |
| CASBUF  | D9      | 03FD, 131    |
| CASFLG  | D8      | 030F, 1      |
| CASINI  | N6      | 0002, 2      |
| CASSBT  | N5      | 004B, 1      |
| CAUX1   | H20     | 023C, 1      |
| CAUX2   | H20     | 023D, 1      |
| CBAUDH  | D1      | 02EF, 1      |
| CBAUDL  | D1      | 02EE, 1      |
| CCOMND  | H19     | 023B, 1      |
| CDEVIC  | H18     | 023A, 1      |
| CDTMA1  | P5, H27 | 0226, 2      |
| CDTMA2  | P7      | 0228, 2      |
| CDTMF3  | P9      | 022A, 1      |
| CDTMF4  | P9      | 022C, 1      |
| CDTMF5  | P9      | 022E, 1      |
| CDTMV1  | P4, H26 | 0226, 2      |
| CDTMV2  | P6      | 021A, 2      |
| CDTMV3  | P8      | 021C, 2      |

|        |         |          |
|--------|---------|----------|
| CDTMV4 | P8      | 021E, 2  |
| CDTMV5 | P8      | 0220, 2  |
| CH     | E3      | 02FC, 1  |
| CHKSNT | H14     | 003B, 1  |
| CH1    | E1      | 02F2, 1  |
| CHACT  | P25     | 02F3, 1  |
| CHAR   | B55     | 02FA, 1  |
| CHBAS  | P26     | 02F4, 1  |
| CHKSNT | H14     | 003B, 1  |
| CHKSUM | H13     | 0031, 1  |
| CIOCHR | G25     | 002F, 1  |
| CIX    | M11     | 00F2, 1  |
| CKEY   | N4      | 004A, 1  |
| COLAC  | B24     | 0072, 2  |
| COLCRS | B2      | 0055, 2  |
| COLDST | N11     | 0244, 1  |
| COLINC | B21     | 007A, 1  |
| COLOR0 | B8, P27 | 02C4, 1  |
| COLOR1 | B8, P27 | 02C5, 1  |
| COLOR2 | B8, P27 | 02C6, 1  |
| COLOR3 | B8, P27 | 02C7, 1  |
| COLOR4 | B8, P27 | 02C8, 1  |
| COLRSH | B11     | 004F, 1  |
| COUNTR | B23     | 007E, 2  |
| CRETRY | H11     | 0036, 1  |
| CRITIC | P1      | 0042, 1  |
| CRSINH | B1      | 02F0, 1  |
| CSTAT  | S2      | 0288, 1  |
| DAUX1  | H9      | 030A, 1  |
| DAUX2  | H9      | 030B, 2  |
| DBSECT | N9      | 0241, 1  |
| DBUFHI | H6      | 0304, 1  |
| DBUFLO | H6      | 0305, 1  |
| DBYTHI | H8      | 0308, 1  |
| DBYTLO | H8      | 0309, 1  |
| DCB    | H1      | 0300, 12 |
| DCOMND | H4      | 0302, 1  |
| DDEVIC | H2      | 0300, 1  |
| DEGFLG | M24     | 00FB, 1  |
| DELTAC | B22     | 0077, 2  |
| DELTAR | B22     | 0076, 1  |
| DFLAGS | N8      | 0240, 1  |
| DIGRT  | M10     | 00F1, 1  |
| DINDEX | B35     | 0057, 1  |
| DMASK  | B28     | 02A0, 1  |
| DOSINI | N3      | 000C, 2  |
| DOSVEC | N12     | 000A, 2  |
| DRETRY | H12     | 0037, 1  |
| DRKMSK | B12     | 004E, 1  |
| DSKTIM | C2      | 0246, 1  |
| DSKUTL | L1      | 001A, 2  |
| DSPFLG | B27     | 02FE, 1  |
| DSTAT  | B34     | 004C, 1  |

|        |     |          |
|--------|-----|----------|
| DSTATS | H5  | 0303, 1  |
| DTIMLO | H7  | 0306, 1  |
| DUNIT  | H3  | 0301, 1  |
| DUNUSE | S3  | 0307, 1  |
| DVSTAT | G11 | 02EA, 4  |
| EEXP   | M6  | 00ED, 1  |
| ENDPT  | B25 | 0074, 2  |
| ERRFLG | H30 | 023F, 1  |
| (ERRNO | K5) | 0049, 1  |
| ESCFLG | B26 | 02A2, 1  |
| ESIGN  | M8  | 00EF, 1  |
| FCHRFL | M9  | 00F0, 1  |
| FEOF   | D12 | 003F, 1  |
| FILDAT | B17 | 02FD, 1  |
| FILFLG | B18 | 02B7, 1  |
| FLPTR  | M16 | 00FC, 2  |
| FMSZPG | K1  | 0043, 7  |
| FPSCR  | M22 | 05E6, 6  |
| FPSCR1 | M23 | 05EC, 6  |
| FPTR2  | M17 | 00FE, 2  |
| FR0    | M1  | 00D4, 6  |
| FR1    | M3  | 00E0, 6  |
| FR2    | M4  | 00E6, 6  |
| FRE    | M2  | 00DA, 6  |
| FREQ   | D15 | 0040, 1  |
| FRMADR | B41 | 0068, 2  |
| FRX    | M5  | 00EC, 1  |
| FSCR   | M22 | 05E6, 6  |
| FSCR1  | M23 | 05EC, 6  |
| FTYPE  | D13 | 003E, 1  |
| GPRIOR | P24 | 026F, 1  |
| HATABS | G12 | 031A, 38 |
| HOLD1  | B30 | 0051, 1  |
| HOLD2  | B31 | 029F, 1  |
| HOLD3  | B32 | 029D, 1  |
| HOLD4  | B20 | 02BC, 1  |
| HOLDCH | E7  | 007C, 1  |
| ICAX1  | G9  | 034A, 1  |
| ICAX1Z | G21 | 002A, 1  |
| ICAX2  | G9  | 034B, 1  |
| ICAX2Z | G21 | 002B, 1  |
| ICBAH  | G6  | 0345, 1  |
| ICBAHZ | G18 | 0025, 1  |
| ICBAL  | G6  | 0344, 1  |
| ICBALZ | G18 | 0024, 1  |
| ICBLH  | G8  | 0349, 1  |
| ICBLHZ | G20 | 0029, 1  |
| ICBLL  | G8  | 0348, 1  |
| ICBLLZ | G20 | 0028, 1  |

|        |         |          |
|--------|---------|----------|
| ICCOM  | G4      | 0342, 1  |
| ICCOMT | G23     | 0017, 1  |
| ICCOMZ | G16     | 0022, 1  |
| ICDNO  | G3      | 0341, 1  |
| ICDNOZ | G15     | 0021, 1  |
| ICHID  | G2      | 0340, 1  |
| ICHIDZ | G14     | 0020, 1  |
| ICIDNO | G24, G2 | 2002E, 1 |
| ICPTH  | G7      | 0347, 1  |
| ICPTHZ | G19     | 0027, 1  |
| ICPTL  | G7      | 0346, 1  |
| ICPTLZ | G19     | 0026, 1  |
| ICSPR  | G10     | 034C, 4  |
| ICSPRZ | G22     | 002C, 4  |
| ICSTA  | G5      | 0343, 1  |
| ICSTAZ | G17     | 0023, 1  |
| INBUFF | M12     | 00F3, 2  |
| INSDAT | B45     | 007D, 1  |
| INTMP  | P28     | 022D, 1  |
| INVFLG | E9      | 02B6, 1  |
| IOCB   | G1      | 0340, 16 |
| IOCBAS | G13     | 0020, 16 |
| KEYDEL | E2      | 02F1, 1  |
| LBFEND | M20     | 0580, 96 |
| LBPR1  | M18     | 057E, 1  |
| LBPR2  | M19     | 057F, 1  |
| LBUFF  | M20     | 0580, 96 |
| LINBUF | B51     | 0247, 40 |
| LMARGN | B5      | 0052, 1  |
| LOGCOL | B15     | 0063, 1  |
| LOGMAP | B14     | 02B2, 4  |
| MEMLO  | A1      | 02E7, 2  |
| MEMTOP | A2      | 02E5, 2  |
| MLTTMP | B40     | 0066, 2  |
| NEWCOL | B19     | 0061, 2  |
| NEWROW | B19     | 0060, 1  |
| NOCKSM | H15     | 003C, 1  |
| NSIGN  | M7      | 00EE, 1  |
| OLDADR | B38     | 005E, 2  |
| OLDCHR | B37     | 005D, 1  |
| OLDCOL | B3      | 005B, 2  |
| OLDROW | B3      | 005A, 1  |
| OPNTMP | B40     | 0066, 2  |
| PADDLO | J3      | 0270, 1  |
| PADDL1 | J3      | 0271, 1  |
| PADDL2 | J3      | 0272, 1  |
| PADDL3 | J3      | 0273, 1  |
| PADDL4 | J3      | 0274, 1  |

|        |         |          |
|--------|---------|----------|
| PADDL5 | J3      | 0275, 1  |
| PADDL6 | J3      | 0276, 1  |
| PADDL7 | J3      | 0277, 1  |
| PBPNT  | F3      | 001D, 1  |
| PBUFSZ | F2      | 001E, 1  |
| PCOLR0 | B7, P27 | 02C0, 1  |
| PCOLR1 | B7, P27 | 02C1, 1  |
| PCOLR2 | B7, P27 | 02C2, 1  |
| PCOLR3 | B7, P27 | 02C3, 1  |
| PLYARG | M21     | 05E0, 6  |
| POKMSK | P2      | 0010, 1  |
| PRNBUF | F1      | 03C0, 40 |
| PTEMP  | F4      | 001F, 1  |
| PTIMOT | F5      | 001C, 1  |
| PTRIG0 | J4      | 027C, 1  |
| PTRIG1 | J4      | 027D, 1  |
| PTRIG2 | J4      | 027E, 1  |
| PTRIG3 | J4      | 027F, 1  |
| PTRIG4 | J4      | 0280, 1  |
| PTRIG5 | J4      | 0281, 1  |
| PTRIG6 | J4      | 0282, 1  |
| PTRIG7 | J4      | 0283, 1  |

|        |     |         |
|--------|-----|---------|
| RADFLG | M24 | 00FB, 1 |
| RAMLO  | N1  | 0004, 3 |
| RAMSIZ | A5  | 02E4, 1 |
| RAMTOP | A4  | 006A, 1 |
| RECVDN | H22 | 0039, 1 |
| RMARGN | B6  | 0053, 1 |
| ROWAC  | B24 | 0070, 2 |
| ROWCRS | B2  | 0054, 1 |
| ROWINC | B21 | 0079, 1 |
| RTCLOK | P3  | 0012, 3 |

|        |            |         |
|--------|------------|---------|
| SAVADR | B41        | 0068, 2 |
| SAVID  | D7         | 0316, 1 |
| SAVMSC | B36        | 0058, 2 |
| SCRFLG | B9         | 02BB, 1 |
| SDLSTH | P23        | 0231, 1 |
| SDLSTL | P23        | 0230, 1 |
| SDMCTL | P22        | 022F, 1 |
| SHFAMT | B29        | 006F, 1 |
| SHFLOK | E6         | 02BE, 1 |
| SOUNDR | H10        | 0041, 1 |
| SRTIMR | E8         | 022B, 1 |
| SSFLAG | E4         | 02FF, 1 |
| SSKCTL | H32        | 0232, 1 |
| STACKP | H28        | 0318, 1 |
| STATUS | H31        | 0030, 1 |
| STICK0 | J1, J7, J8 | 0278, 1 |
| STICK1 | J1, J7, J8 | 0279, 1 |
| STICK2 | J1, J7, J8 | 027A, 1 |
| STICK3 | J1, J7, J8 | 027B, 1 |
| STRIG0 | J2, J7, J9 | 0284, 1 |

|        |            |           |
|--------|------------|-----------|
| STRIG1 | J2, J7, J9 | 0285, 1   |
| STRIG2 | J2, J7, J9 | 0286, 1   |
| STRIG3 | J2, J7, J9 | 0284, 4   |
| SUBTMP | B48        | 029E, 1   |
| SWPFLG | B44        | 007B, 1   |
|        |            |           |
| TABMAP | B13        | 02A3, 15  |
| TEMP   | H23        | 023E, 1   |
| TEMP1  | D5         | 0312, 2   |
| TEMP3  | D6         | 0315, 1   |
| TIMER1 | D3         | 030C, 2   |
| TIMER2 | D3         | 0310, 2   |
| TIMFLG | D2, H25    | 0317, 1   |
| TINDEX | B49        | 0293, 1   |
| TMPCHR | B33        | 0050, 1   |
| TMPCOL | B46        | 02B9, 2   |
| TMPLBT | B47        | 02A1, 1   |
| TMPROW | B46        | 02B8, 1   |
| TOADR  | B40        | 0066, 2   |
| TRAMSZ | N1         | 0004, 3   |
| TSTAT  | H29        | 0319, 1   |
| TSTDAT | N2         | 0007, 1   |
| TXTCOL | B4         | 0291, 2   |
| TXTMSC | B52        | 0294, 2   |
| TXTOLD | B53        | 0296, 6   |
| TXTROW | B4         | 0290, 1   |
|        |            |           |
| USAREA | R1         | 0080, 128 |
|        |            |           |
| VBREAK | P16        | 0206, 2   |
| VDSLST | P10        | 0200, 2   |
| VIMIRG | P13        | 0216, 2   |
| VINTER | P15        | 0204, 2   |
| VKEYBD | P17        | 0208, 2   |
| VPRCED | P14        | 0202, 2   |
| VSERIN | P18        | 020A, 2   |
| VSEROC | P20        | 020E, 2   |
| VSEROR | P19        | 020C, 2   |
| VTIMR1 | P21        | 0210, 2   |
| VTIMR2 | P21        | 0212, 2   |
| VTIMR4 | P21        | 0214, 2   |
| VVBLKD | P12        | 0224, 2   |
| VVBLKI | P11        | 0222, 2   |
|        |            |           |
| WARMST | N13        | 0008, 1   |
| WMODE  | D14        | 0289, 1   |
|        |            |           |
| XMTDON | H24        | 003A, 1   |
|        |            |           |
| (ZBUFF | K2)        | 0043, 2   |
| (ZDRVA | K3)        | 0045, 2   |
| ZIOCB  | G13        | 0020, 16  |
| (ZSBA  | K4)        | 0047, 2   |
| ZTEMP1 | M13        | 00F5, 2   |

ZTEMP3  
ZTEMP4

M15  
M14

00F9,2  
00F7,2

# MEMORY ADDRESS ORDERED LIST OF DATABASE VARIABLES

| ADDRESS   | VID                | NAME                      |
|-----------|--------------------|---------------------------|
| 0000-0001 | S7                 | LNZBS                     |
| 0002-0003 | N6                 | CASINI                    |
| 0004-0006 | N1                 | RAMLO, TRAMSZ             |
| 0007      | N2                 | TSTDAT                    |
| 0008      | N13                | WARMST                    |
| 0009      | N7                 | BOOT?                     |
| 000A-000B | N12                | DOSVEC                    |
| 000C-000D | N3                 | DOSINI                    |
| 000E-000F | A3                 | APPMHI                    |
| 0010      | P2                 | POKMSK                    |
| 0011      | E5                 | BRKKEY                    |
| 0012-0014 | P3                 | RTCLOK                    |
| 0015-0016 | C1                 | BUFADR                    |
| 0017      | G23                | ICCOMT                    |
| 001A-001B | L1                 | DSKUTL                    |
| 001C      | F5                 | PTIMOT                    |
| 001D      | F3                 | PBPNT                     |
| 001E      | F2                 | PBUFSZ                    |
| 001F      | F4                 | PTEMP                     |
| 0020      | G13, G14           | ICHIDZ                    |
| 0021      | G15                | ICDNOZ                    |
| 0022      | G16                | ICCOMZ                    |
| 0023      | G17                | ICOBAS                    |
| 0024-0025 | G18                | ICBALZ, ICBAHZ            |
| 0026-0027 | G19                | ICPTLZ, ICPTHZ            |
| 0028-0029 | G20                | ICBLLZ, ICBLHZ            |
| 002A-002B | G21                | ICAX1Z, ICAX2Z            |
| 002C-002F | G22, G24, G25      | ICSPRZ                    |
| 0030      | H31                | STATUS                    |
| 0031      | H13                | CHKSUM                    |
| 0032-0033 | H16                | BUFRLO, BUFRHI            |
| 0034-0035 | H17                | BFENLO, BFENHI            |
| 0036      | H11                | CRETRY                    |
| 0037      | H12                | DRETRY                    |
| 0038      | H21                | BUFRFL                    |
| 0039      | H22                | RECVDN                    |
| 003A      | H24                | XMTDON                    |
| 003B      | H14                | CHKSNT                    |
| 003C      | H15                | NOCKSM                    |
| 003D      | D11                | BPTR                      |
| 003E      | D13                | FTYPE                     |
| 003F      | D12                | FEOF                      |
| 0040      | D15                | FREQ                      |
| 0041      | H10                | SOUNDR                    |
| 0042      | P1                 | CRITIC                    |
| 0043-0049 | K1, K2, K3, K4, K5 | ZBUFF, ZBUFP, ZDRVA, ZSBA |
| 004A      | N4                 | CKEY                      |
| 004B      | N5                 | CASSBT                    |
| 004C      | B34                | DSTAT                     |

|           |                                          |                        |
|-----------|------------------------------------------|------------------------|
| 004D      | B10                                      | ATTRACT                |
| 004E      | B12                                      | DRKMSK                 |
| 004F      | B11                                      | COLRSH                 |
| 0050      | B33                                      | TMPCHR                 |
| 0051      | B30                                      | HOLD1                  |
| 0052      | B5                                       | LMARGN                 |
| 0053      | B6                                       | RMARGN                 |
| 0054-0056 | B2                                       | ROWCRS, COLCRS         |
| 0057      | B35                                      | DINDEX                 |
| 0058-0059 | B36                                      | SAVMSC                 |
| 005A-005C | B3                                       | OLDROW, OLDCOL         |
| 005D      | B37                                      | OLDCHR                 |
| 005E-005F | B38                                      | OLDADR                 |
| 0060-0062 | B19                                      | NEWROW, NEWCOL         |
| 0063      | B15                                      | LOGCOL                 |
| 0064-0065 | B39                                      | ADRESS                 |
| 0066-0067 | B40                                      | MLTTMP, OPNTMP, TOADR  |
| 0068-0069 | B41                                      | SAVADR/FRMADR          |
| 006A      | A4                                       | RAMTOP                 |
| 006B      | B42                                      | BUFCNT                 |
| 006C-006D | B43                                      | BUFSTR                 |
| 006E      | B50                                      | BITMSK                 |
| 006F      | B29                                      | SHFAMT                 |
| 0070-0073 | B24                                      | ROWAC, COLAC           |
| 0074-0075 | B25                                      | ENDPT                  |
| 0076-0078 | B22                                      | DELTAR, DELTAC         |
| 0079-007A | B21                                      | ROWINC, COLINC         |
| 007B      | B44                                      | SWPFLG                 |
| 007C      | E7                                       | HOLDCH                 |
| 007D      | B45                                      | INSDAT                 |
| 007E-007F | B23                                      | COUNTR                 |
| 0080-00FF | SEE FLOATING POINT VARIABLE LIST AT END. |                        |
| 0100-01FF | 6502 STACK                               |                        |
| 0200-0201 | P10                                      | VDSLST                 |
| 0202-0203 | P14                                      | VPRCED                 |
| 0204-0205 | P15                                      | VINTER                 |
| 0206-0207 | P16                                      | VBREAK                 |
| 0208-0209 | P17                                      | VKEYBD                 |
| 020A-020B | P18                                      | VSERIN                 |
| 020C-020D | P19                                      | VSEROR                 |
| 020E-020F | P20                                      | VSEROC                 |
| 0210-0215 | P21                                      | VITMR1, VITMR2, VITMR4 |
| 0216-0217 | P13                                      | VIMIRG                 |
| 0218-0219 | P4, H26                                  | CDTMV1                 |
| 021A-021B | P6                                       | CDTMV2                 |
| 021C-0221 | P8                                       | CDTMV3, CDTMV4, CDTMV5 |
| 0222-0223 | P11                                      | VVBLKI                 |
| 0224-0225 | P12                                      | VVBLKD                 |
| 0226-0227 | P5, H27                                  | CDTMA1                 |
| 0228-0229 | P7                                       | CDTMA2                 |
| 022A      | P9                                       | CDTMF3                 |

|           |            |                  |
|-----------|------------|------------------|
| 022B      | E8         | SRTIMR           |
| 022C      | P9         | CDTMF4           |
| 022D      | P28        | INTEMP           |
| 022E      | P9         | CDTMF5           |
| 022F      | P22        | SDMCTL           |
| 0230-0231 | P23        | SDLSTL, SDLSTH   |
| 0232      | H32        | SSKCTL           |
| 023A      | H18        | CDEVIC           |
| 023B      | H19        | CCOMND           |
| 023C-023D | H20        | CAUX1, CAUX2     |
| 023E      | H23        | TEMP             |
| 023F      | H30        | ERRFLG           |
| 0240      | N8         | DFLAGS           |
| 0241      | N9         | DBSECT           |
| 0242-0243 | N10        | BOOTAD           |
| 0244      | N11        | COLDST           |
| 0246      | C2         | DSKTIM           |
| 0247-026E | B51        | LINBUF           |
| 026F      | P24        | GPRIDR           |
| 0270-0277 | J3         | PADDL0 -- PADDL7 |
| 0278-027B | J1, J7, J8 | STICK0 -- STICK3 |
| 027C-0283 | J4         | PTRIG0 -- PTRIG7 |
| 0284-0287 | J2, J7, J9 | STRIG0 -- STRIG3 |
| 0289      | D14        | WMODE            |
| 028A      | D10        | BLIM             |
| 028B-028F | S10        | unused           |
| 0290-0292 | B4         | TXTROW, TXTCOL   |
| 0293      | B49        | TINDEX           |
| 0294-0295 | B52        | TXTMSC           |
| 0296-029B | B53        | TXTOLD           |
| 029D      | B32        | HOLD3            |
| 029E      | B48        | SUBTMP           |
| 029F      | B31        | HOLD2            |
| 02A0      | B28        | DMASK            |
| 02A1      | B47        | TMPLBT           |
| 02A2      | B26        | ESCFLG           |
| 02A3-02B1 | B13        | TABMAP           |
| 02B2-02B5 | B14        | LOGMAP           |
| 02B6      | E9         | INVFLG           |
| 02B7      | B18        | FILFLG           |
| 02B8-02BA | B46        | TMPCOL           |
| 02BB      | B9         | SCRFLG           |
| 02BC      | B20        | HOLD4            |
| 02BE      | E6         | SHFLOK           |
| 02BF      | B16        | BOTSCR           |
| 02C0-02C3 | B7, P27    | PCOLR0 -- PCOLR3 |
| 02C4-02C8 | B8, P27    | PCOLR0 -- PCOLR4 |
| 02E4      | A5         | RAMSIZ           |
| 02E5-02E6 | A2         | MEMTOP           |
| 02E7-02E8 | A1         | MEMLO            |
| 02EA-02ED | G11        | DVSTAT           |
| 02EE-02EF | D1         | CHBAUDL, CHBAUDH |
| 02F0      | B1         | CRSINH           |
| 02F1      | E2         | KEYDEL           |

|           |         |                |
|-----------|---------|----------------|
| 02F2      | E1      | CH1            |
| 02F3      | P25     | CHACT          |
| 02F4      | P26     | CHBAS          |
| 02FA      | B55     | CHAR           |
| 02FB      | B54     | ATACHR         |
| 02FC      | E3      | CH             |
| 02FD      | B17     | FILDAT         |
| 02FE      | B27     | DSPFLG         |
| 02FF      | E4      | SSFLAG         |
| 0300      | H1, H2  | DCB/DDEVIC     |
| 0301      | H3      | DUNIT          |
| 0302      | H4      | DCOMND         |
| 0303      | H5      | DSTATS         |
| 0304-0305 | H6      | DBUFLO, DBUFHI |
| 0306      | H7      | DTIMLO         |
| 0308-0309 | H8      | DBYTLO, DBYTHI |
| 030A-030B | H9      | DAUX1, DAUX2   |
| 030C-030D | D3      | TIMER1         |
| 030E      | D4      | ADDCOR         |
| 030F      | D8      | CASFLG         |
| 0310-0311 | D3      | TIMER2         |
| 0312-0313 | D5      | TEMP1          |
| 0315      | D6      | TEMP3          |
| 0316      | D7      | SAVIO          |
| 0317      | D2, H25 | TIMFLG         |
| 0318      | H28     | STACKP         |
| 0319      | H29     | TSTAT          |
| 031A-033F | G12     | HATABS         |
| 0340      | G1, G2  | IOCB, ICHID    |
| 0341      | G3      | ICDNO          |
| 0342      | G4      | ICCOM          |
| 0343      | G5      | ICSTA          |
| 0344-0345 | G6      | ICBAL, ICBAH   |
| 0346-0347 | G7      | ICPTL, ICPTH   |
| 0348-0349 | G8      | ICBLL, ICBLH   |
| 034A-034B | G9      | ICAX1, ICAX2   |
| 034C-034F | G10     | ICSPR          |
| 0350-035F | G2-G10  | (IOCB #1)      |
| 0360-036F | G2-G10  | (IOCB #2)      |
| 0370-037F | G2-G10  | (IOCB #3)      |
| 0380-038F | G2-G10  | (IOCB #4)      |
| 0390-039F | G2-G10  | (IOCB #5)      |
| 03A0-03AF | G2-G10  | (IOCB #6)      |
| 03B0-03BF | G2-G10  | (IOCB #7)      |
| 03C0-03E7 | F1      | PRNBUF         |
| 03FD-047F | D9      | CASBUF         |
| 0480-06FF | R2      | User Area      |

# FLOATING POINT PACKAGE VARIABLES

|           |     |               |
|-----------|-----|---------------|
| 00D4-00D9 | M1  | FRO           |
| 00DA-00DF | M2  | FRE           |
| 00E0-00E5 | M3  | FR1           |
| 00E6-00EB | M4  | FR2           |
| 00EC      | M5  | FRX           |
| 00ED      | M6  | EEXP          |
| 00EE      | M7  | NSIGN         |
| 00EF      | M8  | ESIGN         |
| 00F0      | M9  | FCHRFLG       |
| 00F1      | M10 | DIGRT         |
| 00F2      | M11 | CIX           |
| 00F3-00F4 | M12 | INBUFF        |
| 00F5-00F6 | M13 | ZTEMP1        |
| 00F7-00F8 | M14 | ZTEMP4        |
| 00F9-00FA | M15 | ZTEMP3        |
| 00FB      | M24 | RADFLG/DEGFLG |
| 00FC-00FD | M16 | FLPTR         |
| 00FE-00FF | M17 | FPTR2         |
| 057E      | M18 | LBPR1         |
| 057F      | M19 | LBPR2         |
| 0580-05FF | M20 | LBFEND, LBUFF |
| 05E0-05E5 | M21 | PLYARG        |
| 05E6-05EB | M22 | FPSCR/FSCR    |
| 05EC-05F1 | M23 | FPSCR1/SCR1   |

## INDEX

The subject index contains three forms of references:

Section number, such as '3.'  
 Appendix, such as 'App B'  
 Variable ID from Appendix L, such as 'B7'.

|                                     |                            |
|-------------------------------------|----------------------------|
| ATARI standards                     | 12                         |
| ATASCII                             | B54-55, 5, App D-G         |
| attract mode                        | B10-12, 6,                 |
| bit mapped graphics                 | B28-B29, 5, App H          |
| blackboard mode                     | 3, N12, 7, 12              |
| BNF                                 | 1                          |
| boot                                | 3, 4, N3-10, 5, 7, 10      |
| BREAK                               | E5, 6, 12                  |
| cartridge                           | 3, 4, 7, 10                |
| cassette baud rate determine        | D1-D7                      |
| cassette-boot                       | 3, N3-10, 7, 10            |
| cassette device                     | D1-D15, 3, 5               |
| Cassette Handler (C)                | 5                          |
| CID (Central I/O Utility)           | G1-25, 5, 9                |
| CID/user interface                  | G1-11, 5, App A, App B     |
| CID/Handler interface               | G12-22, 9                  |
| CLOSE I/O command                   | 5, 9                       |
| coldstart (see 'Power-up')          |                            |
| color control                       | B7-8, 5, 6                 |
| control characters                  | B26-27, 5, App D           |
| critical section                    | P1, 6                      |
| cursor                              | B1-4, 5                    |
| database                            | 4                          |
| DCB (Device Control Block)          | H1-9, 5, 9                 |
| DELETE I/O command                  | 5                          |
| development system                  | 13                         |
| device/filename specification       | 5                          |
| Device Handler                      | 5, 9                       |
| device table                        | 2, G12, 5, 7, 9            |
| disk-boot                           | 3, N3-10, 5, 7, 10         |
| disk device                         | 5                          |
| Disk File Manager (D)               | K1-5, 5                    |
| Disk Handler (resident)             | C1-2, 5                    |
| display device (screen)             | B54-55, 5, App E, App H    |
| Display Handler (S)                 | B1-55, 5                   |
| display list                        | 4, P10                     |
| DOS (Disk Utilities)                | L1, 12                     |
| DRAW I/O command                    | B17-25, 5                  |
| driving controller                  | J8-9                       |
| Educational System Format Cassettes | 5                          |
| error handling                      | G5, H5, H11-12, 9, App B-C |

|                                                               |                       |
|---------------------------------------------------------------|-----------------------|
| EOF (end-of-file)                                             | 5                     |
| File Management System                                        | 5                     |
| FILL I/O command                                              | B17-25, 5             |
| floating point package                                        | 2, 4, M1-24, 8, App J |
| FORMAT I/O command                                            | 5                     |
| free memory                                                   | 4, A1-3, R1-2, 4, 7   |
| game controllers                                              | 3, J1-9, 6, 11        |
| GET CHARACTER I/O command                                     | 5, 9                  |
| GET RECORD I/O command                                        | 5, 9                  |
| GET STATUS I/O command                                        | G11, 5, 9             |
| Handler (see 'device handler' and individual device handlers) |                       |
| initialization, cartridge                                     | 7                     |
| initialization, Handler                                       | 7, 9                  |
| initialization, interrupt                                     | 6                     |
| initialization, system                                        | 4, 7, 10              |
| internal display code                                         | 5, B54                |
| interrupts                                                    | 2, P1-28, 6           |
| interrupt mask                                                | P2, 6                 |
| inverse video (display)                                       | E9, 5                 |
| I/O                                                           | 2, 4, 5, 9            |
| IOCB (I/O Control Block)                                      | G1-10, 5, 9           |
| I/O retry logic                                               | H11-12                |
| joystick                                                      | J1-2                  |
| keyboard Autorepeat                                           | E8                    |
| keyboard device                                               | 5                     |
| Keyboard Handler (K)                                          | E1-9, 5, App F        |
| keyboard key debouncing                                       | E1-3                  |
| light pen                                                     | 11, App J             |
| LNBUG                                                         | 13                    |
| LOCK I/O command                                              | 5                     |
| logical text lines (screen)                                   | B14-15, 5             |
| memory (see 'RAM', 'ROM' and 'free memory')                   |                       |
| memory dynamics                                               | A1-5, N1-2, 4, 5, 7   |
| memory map                                                    | 4                     |
| NOTE I/O command                                              | 5                     |
| OPEN I/O command                                              | 5, 9                  |
| paddle                                                        | J3-4                  |
| page 0                                                        | 4, M1-17, R1, 9       |
| page 1                                                        | 4, 9                  |
| peripheral devices                                            | 3                     |
| POINT I/O command                                             | 5                     |
| Power-up                                                      | 2, N1-13, 4, 7, 12    |
| printer device                                                | 5, App G              |

|                              |                            |
|------------------------------|----------------------------|
| Printer Handler (P)          | F1-5, 5                    |
| program development          | 13                         |
| PUT CHARACTER I/O command    | 5, 9                       |
| PUT RECORD I/O command       | 5, 9                       |
| RAM                          | 3, 4, 9                    |
| record (I/O)                 | 5                          |
| RENAME I/O command           | 5                          |
| RESET                        | 2, N1-13, 6, 7, 12         |
| ROM (OS)                     | 1, 4                       |
| RS-232-C Handler (R)         | 5, 9                       |
| Screen Editor (E)            | B1-55, 5                   |
| screen margins               | B5-6, 5, 7                 |
| screen modes                 | 4, 5, App H                |
| scrolling (text)             | B9, 5                      |
| serial I/O bus               | 3, 5, 9, App I             |
| [SHIFT]/CONTROL lock         | E6-7, 5                    |
| SIO (Serial bus I/O Utility) | H1-32, P13-21, 5, 9, App C |
| sound control (SIO)          | H10, 11                    |
| SPECIAL I/O commands         | 5, 9                       |
| split screen                 | B16, 5                     |
| stack                        | 4                          |
| start/stop (display)         | E4, 5, 12                  |
| stage 1 VBLANK process       | P3-5, 6                    |
| stage 2 VBLANK process       | P6-9, P22-27, 6            |
| tabs (Screen Editor)         | B13, 5                     |
| timeout (device)             | H25-27, 9                  |
| timers (system)              | P3-9, 6                    |
| UNLOCK I/O command           | 5                          |
| user workspace               | 4, M18-23, R2              |
| vectors, RAM                 | P5, P7, P10-21, 6, 9       |
| vectors, ROM                 | 5, 9, App J                |
| vertical blank interrupt     | P11-12, 6                  |
| warmstart (see 'RESET')      |                            |
| wild-card (disk filename)    | 5                          |
| ZIOCB (Zero-page IOCB)       | G13-22, 9, 0020, 16        |